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NEW SERIES, VOLUME XLIV

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EDITORIAL

SURGERY OF THE EXTREMITIES

FOR locomotion, prehension and much of sensory appreciation, we depend on our extremities. The mechanical phases of surgery in this field are largely the concern of the orthopedist. The newer speciality of industrial surgery is utilitarian. It considers disability of the employed workman in the light of his earning capacity. The period of disability and ability to keep on the job are considered more important than cosmetic result. A hand that will enable a man to work, even though unsightly and shorn of some of its digits, may be preferable to an intact member with impaired function. Thus, the surgery of the extremities is often to be adapted to the individual and to his mode of life.

Unfortunately many injuries of the extremities are yet treated by those with little surgical experience. Fortunately, however, the intern no longer takes pride in the number of amputations he has done during his dispensary service. The importance of conserving the hand and its parts seems much more widely appreciated than formerly. Many apparently hopelessly crushed limbs recover in quite an amazing way if secondary skin tension is prevented by immediate long volar and dorsal incisions through the skin. Instead of closing the badly contused wound with sutures, it is better to lay it widely open. A common mistake was to suture meticulously the various divided structures, whereby the limited remaining vitality as well as the resistance to gas bacillus or other infection was lost through the manipulation, or strangled by the secondary swelling and tension of the skin. By delay and with the part living and revitalized, the suture of the divided nerves, tendons and the like may be done with relative safety. A second mistake was to do a primary amputation without waiting to determine viability; or to sacrifice an important part of the hand or foot to obtain skin flaps, instead of depending upon the later transfer of pedicled

flaps or full thickness skin grafts from another part of the body.

With infections of the extremities, as of other parts, it is well to bear in mind the two great clinical types of infection. In the first, early operation kills; in the second, delay in operating may be fatal. In streptococcal infections the onset tends to occur within a few hours after inoculation, the general reaction is severe and the marked local serous edema is often mistaken for suppuration. Ill-timed incisions and manipulations in such cases often lead to a fatal blood stream infection. For anthrax also the older aggressive local treatment with scalpel, cautery and injections of antiseptics had a mortality of about 40 per cent. With complete rest, local protection and immobilization, the mortality has fallen to about 5 per cent. Staphylococcal infections, on the contrary, are associated with a surrounding and isolating zone of vascular thrombi which is protective. There is, as a rule, little danger of a fatal bacteremia, and an early venting of the pus is desirable. Staphylococci commonly infect the skin or bone, but it is to be remembered that the osteomyelitis of infancy differs from the more common form of childhood and later life, in being streptococcal and, like the empyema or other infections of similar cause has the lowest mortality when operation is delayed. A staphylococcic osteomyelitis may be aborted very early merely by drilling the overlying skin and bone in a number of places with an ordinary gimlet as suggested by John B. Murphy. Extensive destruction of bone and increased mortality follow delay in operating. Even more urgent is early operation in gas gangrene, and it is a good rule, where hemorrhage is not a factor, to consider every case of prolonged or secondary shock after trauma of an extremity, as due to gas gangrene until the possibility of this infection has been excluded.

By remembering that lymphangitis and lymphadenitis commonly have a portal of entry in the distant tributary lymph fields a puzzling infection may often be solved. With a patient seen recently, for three years in the dead of winter and in the middle of the night a mysterious red painful swelling suddenly involved the calf of the leg, to incapacitate him for three months or more. For another somewhat similar condition sulfanilamide had been given for four months. In each case the mystery was dispelled by looking between the toes. The first patient considered himself cured within twenty-four hours after he had used a permanganate foot bath for the dermatomycosis. Quite different was a pale, pulseless, extremely painful leg that had shown only a few weeks of improvement after arterial sympathectomies under two surgeons. At consultation a high amputation was advised, but it was finally shown that it was the complete bed rest that had given the relief after the two operations and with this as a guide the patient retained his leg and lived quite comfortably a number of years until the inadequate heart finally gave out. Thus the dermatologist and cardiologist are among those who may aid the surgeon in treating certain affections of the extremities.

W. Wayne Babcock.

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ORIGINAL ARTICLES

VARIETIES OF THROMBOPHLEBITIS OF THE LIMBS

THEIR ORIGIN, COURSE AND TREATMENT

JOHN HOMANS, M.D.

BOSTON, MASSACHUSETTS

ANY account of the known varieties of thrombophlebitis would be incomplete without some explanation of the influences which cause them to arise. For the purposes of the subsequent descriptions, the brief statements made under the following headings (some of which may be disputed) will be held to be significant:

1. *Retardation of the Venous Return.* This is probably of the first importance. It comes about most naturally during life in bed. The general circulation may be feeble because of heart failure and serious debilitating diseases; or, following operation or injury, because of the increased abdominal pressure of tight dressings and intestinal distention; or, because of a reclining position in bed, the body being raised and the legs relaxed (loss of muscular effort in forwarding venous blood toward the heart); or, during active life, because of abdominal adiposity or excessive abdominal tension; or, because the veins of the legs are exposed to unnatural congestion, momentary or otherwise.

2. *Anatomic Relations in the Veins of the Limbs.* The areas in the lower half of the body especially liable to thrombosis are shown in Figure 1. The left common iliac vein passes at a right angle under the right common iliac artery, thereby exposing its stream to especial retardation. Each external iliac vein passes behind a hypogastric artery. There are many entering veins causing confused currents in the region of the inguinal ligament and in the upper calf and popliteal space. These and the large valves in this area combine to make eddies in which the thrombocyte (the active villain in thrombosis) tends to settle and adhere.

3. *Changes in the Blood, including Dehydration.* These relate chiefly to the factors which favor or oppose coagulation and are the subjects of Bancroft's "clotting index." The blood may be affected by diet and drugs, and may be dehydrated by bleeding, vomiting or excessive sweating, whether at the operating table or during an illness. Such influences, especially the dehydrating factors, tend to be preventable and remediable.

4. *Trauma.* This is a mysterious influence which I have elsewhere called the "X" factor. It seems often to touch off the thrombosis when the background is favorable. It may take the form of a minor accident or serious fracture, childbirth or an abdominal operation. That it acts promptly is to be inferred from the accepted tendency today to commence precautions against thrombosis immediately after surgical operations, not some days later. Thromboses are apt to arise upon the same side as the injury, even though the fracture, if such has occurred, lies well away from the thrombosed vein. There is sometimes a suggestion of allergy about the influence of trauma.

5. *Perivascular Inflammation.* This factor is as yet little understood. Explorations by various investigators have shown that in many but not all instances of femoroiliac thrombophlebitis there is a non-suppurative, very vascular exudate about the thrombosed vein and the companion ar-

tery, that is, about the arteriovenous bundle including the lymphatics. The origin of this is obscure, but that it is not uncommon can be implied from the arterial spasms both immediate and late which occasionally complicate phlegmasia alba dolens (femoroiliac thrombosis). That is to say, something evidently irritates the wall of the great vein and artery producing thrombosis in the former and a state of spasm in the latter. The condition of the thrombus itself can hardly account for such inflammation, which seems a primary, not a secondary phenomenon. Nevertheless, as already stated, it is not always present, nor is arterial spasm often demonstrable.

6. *The plexuses of veins draining respectively the uterus and prostate* are undoubtedly the scene of thrombosis, but as yet there is no known detectable symptom-complex. If the thrombosis which is thought to occur in these veins gives rise to embolism, the matter must be of great importance.

7. *Outspoken thrombosis* seldom causes pulmonary embolism. *Quiet* and actually *symptomless processes* are very apt to do so. The matter is related to the reaction in the vein's wall. Thrombosis in varicose veins, for instance, the walls of which are obviously diseased, almost never causes embolism, and phlegmasia alba dolens, when attended by swelling and fever, does so relatively seldom. By contrast, the unnoticed thromboses often cause embolism. It must be supposed that the less changed or inflamed the vein's wall the less secure the thrombus and the more frequent the embolism.

8. *The propagating thrombus*, the cause of embolism, is most apt to form an association with quiet thrombosis and in a slow stream. It represents a soft, friable, floating clot so attached that it waves in the current of an entering vein proximal to the thrombus or grows into the open principal vein from a thrombosed branch. Small and short detached clots cause pulmonary infarction. Large ones cause fatal pulmonary embolism. Most fatal ones are 10 to 12 inches long or are composed of many short thick fragments.

VARIETIES OF THROMBOPHLEBITIS

Phlegmasia Alba Dolens: Femoroiliac Thrombophlebitis or Milk Leg. This is the common "phlebitis" of the laity, the cause of the great white swollen leg—usually an outspoken disease, sometimes painful, especially at its onset. Its scene is the principal vein draining the leg in the region of the groin. It leads to embolism in a rather small proportion of cases, yet the total number of femoroiliac thromboses is so great that it is in fact a fairly common cause of pulmonary embolism.

Though instances of femoroiliac thromboses occurring during active life have been collected by Barker, the disease usually attacks those who, for one reason or another, are confined to bed. The veins involved are the upper femoral, the external and perhaps the common iliac. Slowing of the stream and the eddies and cross currents already described are certainly factors in causing this disease. Aschoff remarks that when both sides are affected the process is likely to extend, on the left, through the common iliac vein and on the right only as high as the inguinal ligament. However, the process often stops cleanly on either side at the point where the external iliac vein passes behind the hypogastric.

Phlegmasia alba dolens is particularly apt to follow operation or injury in persons in or beyond middle life. However, it occurs so frequently in young women after childbirth and often enough in young adults of either sex after acute fevers or such a simple operation as appendicectomy, as to make any categorical statement about a particular age incidence absurd. It would be better to say that a femoroiliac thrombosis comes especially to mind when any sort of operation is proposed for an individual of 55 years or over. After an operation upon the prostate or hysterectomy for

fibroids it is perhaps twice as frequent as after upper abdominal procedures. Surgeons are apt to forget how very often a combining to offer an ideal background for the disease. Reasons have already been given for believing that the initial throm-

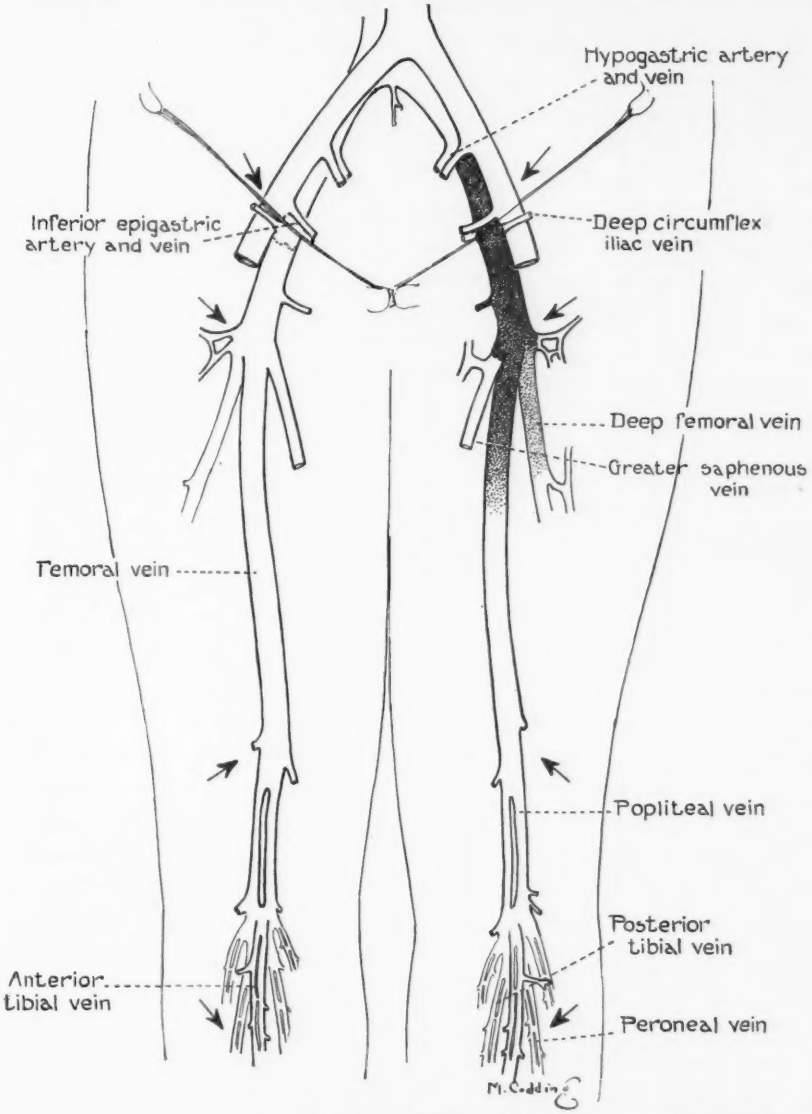

Fig. 1. The principal veins of the lower limbs. Arrows point to the situations anatomically favorable to the formation of a thrombus. On the right is a diagrammatic representation of a left-sided femoroiliac thrombophlebitis. The process ends cleanly (proximally) beneath the hypogastric artery. The distal end of the thrombus is left intentionally vague. The process is shown as not invading extensively the entering branches which are able to carry on a collateral circulation. Variations upon such an arrangement can be imagined.

phlegmasia alba dolens is associated with debilitating conditions—not only the serious, acute fevers like pneumonia and typhoid, but circulatory failures and advanced organic diseases of any sort. Fractures of the lower limbs occasionally bring it on, the injury, plus immobilization of the leg, plus the reclining position so often used

bosis usually starts very promptly after favorable conditions for its establishment have occurred. How soon it *shows* itself thereafter seems to depend upon developments little understood.

When a whole lower limb is swollen, it is certain that a femoroiliac thrombophlebitis is present, but absence of edema

is no proof that the disease does not exist. The amount of edema seems to depend upon the extent of the process, the efficiency of the collateral circulation, and the degree to which the deep lymphatics are obstructed. Naturally a very extensive thrombosis makes the prompt establishment of a collateral circulation a difficult matter, whereas a local one is easily circumvented. Insidious onset and development are consistent with an absence of edema. By contrast, a very acute, active process will cause the limb to swell so tensely, within a period of seventy-two hours, that it will not pit on pressure and is utterly unwieldy. A leg of this sort is not cyanotic and, though a sufficiently widespread thrombosis is perfectly capable, by itself, of causing an advanced edema, one cannot help thinking that lymphatic obstruction is very much concerned with the swelling. Paine looks upon an almost pure lymphedema as being exceedingly common. The writer, though recognizing the perivascular inflammation which Cruveilhier, Leriche and he have demonstrated in their several ways, to be a probable cause of lymphedema, is aware that a very full swelling of a limb can be present without any perivascular involvement of the lymphatics whatever. This de Takats has experimentally proved.

The onset of phlegmasia alba dolens is more often than not ushered in by pain, sometimes of such severity as to suggest acute arterial ischemia. The pain is referred to the groin, the inner face of the thigh, even to the back of the knee or calf. With this there is apt to be some degree of soreness over the upper femoral region and sometimes above the inguinal ligament; but the swelling may appear insidiously, without pain or at the most with a feeling of numbness or heaviness. As a rule, the pain is preceded for twenty-four hours by a moderate elevation of pulse and some rise of temperature. It is not followed by swelling for perhaps another day. Then edema mounts rapidly from the ankle to the groin.

The peripheral arterial pulse in the affected extremity is sometimes decidedly weakened. It may even disappear, in which case the leg becomes cold, bloodless and presents the appearance associated with arterial embolism or thrombosis. Many instances have now been recorded, notably in the French literature (Audier), of arterial spasm on the grand scale, so serious as to result in gangrene of the limb. Indeed, explorations have actually been known to disclose a shrunken femoral artery, lying beside a thrombosed vein (Gregoire). Leriche, who has always stressed the vasomotor disorders of thrombophlebitis as a cause of discomfort and edema, has gone so far as to treat the early stages of femoroiliac thrombophlebitis by daily injections of procaine into the lumbar sympathetic chain which supplies the diseased leg. By securing a vasodilatation in this way, vascular spasm is thought to be reduced, the discomfort lessened and the circulation improved.

The idea of a vascular spasm, venous perhaps as well as arterial, is consistent with the observed after-effect of occasional instances of phlegmasia alba dolens. I am beginning to see more and more often individuals suffering from obvious *chronic* vasomotor spasm following phlegmasia alba dolens. Their legs are a little cyanotic, a little edematous and rarely hypersensitive and painful. That is, a state somewhat resembling reflex edema, reflex dystrophy or causalgia occasionally develops—a vicious circle undoubtedly related to the perivascular inflammation at the scene of the original thrombosis. Postphlebitic indurations and ulcers, not directly related to stasis in the veins themselves, are of course common and may be of a somewhat similar origin.

The course of a femoroiliac thrombophlebitis is extraordinarily variable. A mild form causes only a moderate swelling which disappears after ten days or so and leads to almost no residual edema when the patient first gets about. A severe form, associated with fever and both local and

general discomfort, results in a huge, hard limb which changes little over many weeks or even months. When at last the swelling goes down, the patient is sometimes left with a limb larger than its mate and subject throughout life to some degree of edema, especially of the ankle and lower leg. Once a femoroiliac thrombosis is established, some individuals seem to become increasingly thrombophilic. The opposite leg is involved far more often than is generally supposed, but perhaps so quietly and with so little swelling that the second process is overlooked. Occasionally a thrombophlebitis passes back and forth from one leg to another, recurring later in the one first attacked.

The appearance of the leg is usually one of white swelling. There may be a faintly cyanotic color, as if there were present a generalized peripheral vasoconstriction. Veins are rarely visible, but as the swelling goes down, large, seemingly collateral vessels sometimes appear in the upper thigh, the pubic region and the lower abdomen, remaining throughout life. Occasionally, the great saphenous vein can vaguely be felt as a tender thrombosed cord which later becomes varicose. Far more often, tenderness over the upper femoral canal gives rise to the suspicion of a superficial thrombophlebitis which, in fact, does not exist. The leg is not noticeably hot or cool. Only very occasionally are any lymphatic streaks to be seen.

The aftermath of a phlegmasia alba dolens is usually far less disabling than might be supposed. It is inconceivable, of course, that any valves involved in thrombosis can again function normally, yet very few feet are left cyanotic after the upright position is resumed. The ankle may be puffy but the toes are not blue. Only occasionally, large veins are left which in time become varicose. The probability is that the worst of the thrombosis takes place in the external iliac, where only one valve is occasionally present, and in the upper femoral where after all only a few are lost. Collateral vessels help out and the deep veins of the *lower* leg are seldom involved. The real difficulty is with the perivascular and superficial tissues, as has already been told.

Preventive Treatment. Certain influences favoring thrombosis are unavoidable: in particular, the anatomic and physiologic peculiarities of the venous return from the legs, the exciting traumatic factor, debilitating disease and, of course, life in bed. To these are added the more or less avoidable influences of dependency and immobilization of the lower limbs, increased abdominal tension and dehydration. The first set can be minimized; the second, in most cases, eliminated. Elevation of the legs opposes the anatomic and physiologic difficulty with the venous return. The legs and indeed the body in general can be exercised, preventing relaxation and atrophy. Increased intra-abdominal tension can be prevented by perfect closure of wounds, loose dressings and the skilful anticipation of intestinal distention. The trouble with all such measures is that in nineteen cases out of twenty they are not required—one must go gunning for the twentieth case! One should never, however, leave a patient, weakened by operation or disease, sitting up in bed for more than a few hours at a time. A permanent sitting or even reclining position, the legs being relaxed, is an invitation to thrombosis of the quiet type which so often causes embolism. The patient about whom one is especially nervous should be kept supine or even head downward until he is ready to begin getting out of bed. Indeed, unless the patient has a very vulnerable cardiorespiratory system, an elderly man subjected to prostatectomy had better remain, during the postoperative period, head down and feet up for a good part of each twenty-four hours.

The prevention of increased intra-abdominal tension has been dealt with by Bancroft and his associates. They insist that abdominal wounds be so carefully closed that tight strapping and binders are not needed and they regard the prompt

restoration of intestinal tone by the early use of semi-solid or solid food as essential. Probably the surgeon's handling of the abdominal viscera at the operating table is equally important. An adequate fluid balance, as Coller and his co-workers have proved, merely requires an intelligent calculation. In these days, glucose (5 per cent) and physiologic saline solution are given, intravenously for the most part, according to the particular indications.

Measures directed against thrombosis should start at the earliest possible moment, not several days after the exciting factor has appeared. This has been realized by Best and his associates in Toronto in giving purified heparin after major operations. By establishing, within an hour or two of operation, a continuous intravenous injection at an appropriate dosage, they raise the coagulation time to fifteen minutes, maintaining it at this point for several days. Thus they have decidedly lowered, in a long series of cases, the incidence of thrombosis and embolism. The presence of heparin not only delays coagulation but prevents adhesion of the thrombocyte; that is, it completely abolishes thrombosis. Unfortunately, the treatment is expensive, and is certainly not available for general use. One may properly depend upon Bancroft's clotting index as a measure of the threat of thrombosis, taking special precautions or using an anticoagulant drug for the case in which thrombosis seems imminent. For an account of the test, Bancroft's writing should be consulted.

An index of over 1. points to a tendency to thrombosis and the need of preparing the patient by the use of a high protein, low fat and carbohydrate diet. Whether or not this diet is given, sodium thiosulfate in 10 per cent solution is administered intravenously for three consecutive days in a daily dose of 10 c.c.

The treatment of established thrombosis must always hasten the return of blood from the legs and pelvis. A solid thrombus, it must be supposed, occupies the upper femoral and more or less of the iliac vein. But now the question arises: is a loose, detachable, propagating clot present at the proximal end of the thrombus? In the usual outspoken phlegmasia alba dolens it is very rarely present; in the occasional quiet, barely noticeable thrombophlebitis it may well be. However, the only clear proof of its existence is the occurrence of a pulmonary infarction due to a non-fatal embolus. Therefore, unless one believes that the common iliac vein or vena cava should be divided rather often on suspicion, the possible presence of the propagating process must be ignored and all efforts directed against its *formation*. It isn't the patient's turning over in bed which is responsible for the fatal embolism, but the presence of the detachable embolus; and the best practical defense against the formation of the embolus is elevation of the lower limbs.

Elevation of the legs has two objects: the hurrying of a collateral stream past the proximal end of the thrombus, to prevent the growth of the fragile clot which a slow stream encourages, and the relief of edema. There is no reason why the leg should not be elevated and no reason against its being moved, the proximal end of the thrombus being within the pelvis and little influenced by such factors. Indeed, why worry about casual exercise when the patient must practice daily the athletic feat of using the bed pan? Therefore the foot of the bed should be raised 4 to 6 inches and the swollen leg elevated still more upon an inclined plane or in a sling, as de Takats has suggested. A couple of pillows may be placed under the shoulders and head, but the body should not be bent by raising the upper half of the adjustable bed. Under these conditions, the leg will have freedom of motion and should not be covered with ice bags. Beyond the fact that heat usually brings more comfort —if the thigh is painful—the ice bag delays the flow of blood rather than hastens it and occasionally inflicts a frostbite. The old custom was to sit the patient up in bed, the flaccid legs outstretched, apply ice and wait for swelling and fever to subside. The ideal system is to raise the limb above the body,

allow it some exercise and even to accelerate the drainage of fluid by diuretics. Whether the existence of fever is actually an important consideration is unknown to the writer. When present, as is usually the case, it may be expected to fall with the edema.

Under the system here described, as edema disappears, active exercise of the leg or legs in bed is begun and should be continued, with assistance if necessary, for some days before the patient is encouraged to get up. Then, with bandages applied up to the knee, he begins to walk, going to bed between his early attempts. From this time on, the use of the legs must slowly and regularly be increased. A return of edema is of course a sign of too much dependence and too little elevation. Standing, or sitting with the legs dependent, encourages swelling. Muscular exercise in any position diminishes it.

Should pulmonary infarction occur, the question of dividing a great vein proximal to the thrombus comes up. For those who have not as yet been treated by elevation of the lower half of the body, the answer is easy. Let elevation be tried first. But should infarction occur while the patient is being exposed to the favorable effect of elevation, the answer is difficult. The proximal end of the thrombus is in the external or perhaps the common iliac vein. Suppose that these veins are approached transperitoneally, as by a midline incision, or exposed retroperitoneally from the direction of the crest of the ilium, the operator must then determine, perhaps through an outspoken perivascular inflammation, the upper limit of the thrombus, which may be very soft, and he must hope to divide the vein above any free portion which may be present. The operation may be worth trying in a desperate situation but until methods* not now available are devised to reveal the exact situation of the thrombus and any propagating clot which may be present, it had better not be attempted.

Thrombosis of the Axillary Vein. This rare form is seen almost invariably in young or middle-aged adults and appears to result from some unaccustomed effort—hence the name "thrombite par effort" bestowed upon it by the French. It has been thought that during expiratory engorgement of the axillary vein, the arm being abducted, the costocoracoid ligament indents the vessel (Lowenstein) or the subclavius muscle stretches the vein's wall and injures a certain large valve (Gould and Patey). However that may be, the right arm is usually affected or, if the left has been especially abused, the lesion will sometimes occur on this side.

The usual story is that after some rather strained exertion with the arm elevated, pain or swelling or both develop, and in the following day or two the whole arm becomes edematous and somewhat cyanosed. The superficial veins of the shoulder may be noticeable and a cord or elongated lump can be felt in the course of the axillary vein. Occasionally the process may extend down the brachial to the elbow. As a result of rest in bed, the arm being supported on a pillow away from the side, the swelling disappears, rather more rapidly than is the case with phlegmasia alba dolens. It may be gone in ten days to two weeks, leaving behind only a good-sized vein or two about the shoulder, a temporary stiffness and no permanent after-effects. Apparently there is very little danger of embolism.

Complications do, however, occasionally ensue. The individual may be left with some degree of vasospasm which shows itself in coldness of the hand, perhaps a slightly diminished blood pressure and some crampy feeling—a sort of intermittent limp—on prolonged exercise of the fingers and hand. In my only contact with a case of this sort, the end result of such a state of seemingly reflex arterial spasm has not yet become clear. Venous engorgement, save for some goodsized veins about the shoulder is absent.

* Venography by means of injected solutions opaque to the *x*-ray. An excellent paper on this subject by Dos Santos has recently appeared in the *Journal International de Chirurgie.*

Thrombophlebitis in the Prostatic and Uterine Veins. Thromboses found at autopsy in these vessels have indicated them to be a source of fatal pulmonary embolism, especially when no other source is discovered. Probably thrombosis is able to progress from the plexus of veins draining the prostate or the uterus through the hypogastric vein into the common iliac, obstructing the return from the leg and causing phlegmasia alba dolens. Indeed such must be an occasional cause of that disease. But may a long, non-obstructing, loose clot spring from a prostatic or uterine vein and may it break off leaving only the parent thrombus deep in the pelvis? That seems to be unknown. There is certainly no way of identifying such a process during life. One can only hope that the routine treatment intended to forestall a femoroiliac thrombophlebitis will prevent its occurrence.

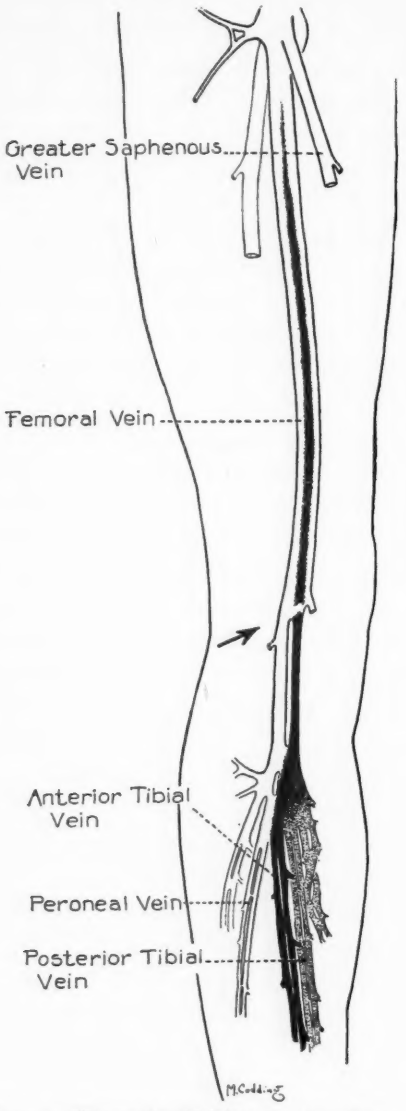

Fig. 2. Thrombophlebitis in the deep veins of the calf (from an autopsy description). A propagating thrombus is shown as if it had just broken off—arrow indicates point of rupture—a typical, long, fatal embolus, certain to cause death by plugging the pulmonary vessels.

Thrombosis in the Deep Veins of the Lower Leg: Deep Peripheral Thrombophlebitis. This treacherous disease has been little described. It occurs during active life and not as a result of the events which lead to a femoroiliac process. Indeed its cause is usually trivial, a minor injury below the knee, a strain, a fracture of one of the bones of the foot, something which usually produces no such effect. It has been known to complicate a respiratory infection or an old rheumatic condition.

The veins involved are one group or several groups in and among the great flat muscles of the calf, some part of the posterior tibial, peroneal or anterior tibial systems; and since there are many more of these veins than are needed except when the muscles are at full use, hardly a sign of venous stasis, under a condition of rest, need appear. The first symptom of disease is usually a little lameness on forced dorsiflexion of the foot, or in putting the weight on the toes, as in walking up stairs. The ankle, perhaps the whole lower leg, may be slightly swollen, the foot a little cyanotic. However, the local signs tend to seem unimportant, and if the patient goes to bed for a few days they entirely disappear. There is usually no tenderness even on deep pressure into the calf. However, no sooner has the individual, from whose leg three or four days in bed have entirely driven the initial soreness and swelling, begun to go about again than the early signs return. Let him rest and exercise, rest and exercise, as in a case subsequently to be described, and he runs a

fair chance of dying of pulmonary embolism. For it is under such conditions that the long propagating thrombus is most apt to form.

The diagnosis is made upon the clinical events described in the preceding paragraph and upon a sign which in my experience seems pathognomonic. This is a sense of discomfort experienced by the patient when the tendo Achillis is put upon the stretch by forced *passive* dorsiflexion of the foot. The discomfort is felt back of the upper calf and knee. This is usually associated with some limitation of the movement attempted. The difference between the two legs is usually very clear to the patient. Not only is this test useful in diagnosis but in following the progress of the disease, for with healing of the thrombosis and the reëstablishment of a normal circulation, the sign disappears.

Treatment varies with the stage at which disease is first seen. If the patient has but just complained of lameness and now for the first time exhibits a slightly swollen, bluish foot and soreness on forced dorsiflexion, conservative treatment should be tried. The lower end of the bed is raised on blocks 4 to 6 inches above the upper, and the leg is placed on a soft pillow. A large cradle is used to keep the bedclothes off the feet. No restriction is placed on moving the leg, but on the other hand no special attempt is made to exercise it. A couple of pillows may be placed under the head and shoulders. If the patient is able easily to manage the bed pan for defecation he should do so. If not, he had better get up once a day (applying a semi-elastic bandage from toes to knee) and use the bedroom cabinet.

Elevation in bed is maintained for at least ten days or until edema and all signs of soreness on forced dorsiflexion of the foot have disappeared. The next four or five days are spent in gently exercising all the muscles of the leg in bed. For it is held that such exercise should precede getting up and that a propagating thrombus need not at this time be feared. Then the patient begins to get about, wearing, when he first walks, a semi-elastic bandage from toes to knee. He feels his way along, walking a little and again elevating the leg, gradually increasing the periods of use and shortening those of rest. If no swelling or blueness of the foot is noticed, an active life is resumed, the whole period of treatment having lasted three to five weeks.

If, on getting about, swelling and cyanosis recur or if the patient is first seen when he (or she) has already, during several weeks, undergone successive periods of elevation, apparent recovery and a return of the original signs, the femoral vein is at once divided distal to the profunda. For it is believed that thrombosis is still then active—is even perhaps extending—and that a propagating thrombus may well be growing up the femoral vein. There is all the more reason for femoral division in that experience has shown such treatment to cure the disease with remarkable rapidity. Of course it removes the danger of pulmonary embolism, and though one might suppose that division, even below the profunda femoris, would cause, for a moment at least, cyanosis of the foot, no such thing happens. The foot, which is usually a little cold, becomes warmer and even perhaps pinker than the other. In other words, a peripheral vasodilatation occurs.

Division of the femoral is performed under local infiltration with procaine. A 10 to 12 cm. oblique incision parallel to the inguinal ligament and about 3 cm. below it is satisfactory. The great saphenous vein is first found and is preserved as the best guide to the femoral. With retraction upward and downward upon the parts superficial to the aponeurosis, this layer is divided peripherally from the saphenous opening, exposing the common femoral just proximal to its division. Perhaps 2 or 3 cm. of the superficial femoral are isolated, ligatures are applied, the proximal just distal to the profunda, and the vein is divided between them. This gives a good cuff both proximally and distally. If a segment is to

be excised, a longer exposure of the vein is needed. The wound is closed in layers with fine silk and requires only a local dressing.

Following femoral division or resection, the patient remains in bed, the foot of which is kept elevated 4 to 6 inches, for a week or for such a period as the surgeon feels is required for the healing of the wound. The thrombosis is no longer important. The lower leg is bandaged when walking is begun, but a normal life can soon be resumed. In my own experience, cyanosis is not afterwards noticeable, but a little edema on hard usage of the leg may be present for some months.

Three typical cases of this disease are briefly described below. The first resulted in death from pulmonary embolism, the second was cured by conservative treatment and in the third, the superficial femoral vein was divided.

N. C., an active man, 50 years of age, suffered a fracture of the fifth metatarsal bone in a minor accident. A plaster cast was applied for a week. For the next four months swelling of the ankle and moderate discomfort in the calf occurred repeatedly upon use of the leg and rapidly disappeared upon rest in bed. At the end of this period he died of pulmonary embolism. The 12 to 15 inch embolus was found to have been detached from the point at which a large thrombosed vein joined the popliteal, as shown in Figure 2. The femoral vein was never occluded. Here was a fatal, easily detached, propagating clot, encouraged to form by partial occlusion of, and retardation of the current in, the venous tree and never subjected to continuous elevation.

By contrast, prompt elevation following the establishment of thrombosis in these same vessels seems to have a favorable effect and is likely to cause the thrombosing process to recede and heal. The following is a case in point:

J. M. H., a vigorous athletic man, 27 years of age, was first seen when, some four days after jumping a brook, one leg had become lame, the ankle and calf considerably swollen but without any ecchymosis. He displayed the sign, already described, which I believe to be characteristic of this disease, that is, a painful soreness noticed high up in the back of the calf upon forced dorsiflexion of the foot, by which the tendo Achillis is put on the stretch. The foot of his bed was elevated 6 inches; the leg placed on a soft pillow but not immobilized. In a week, the swelling had disappeared. In ten days, all soreness on passive dorsiflexion of the foot had gone. Free exercise of the leg in bed was then begun, and in three weeks the patient was going about as usual. There has been no recurrence.

R. C., an active man, 48 years of age, severely wrenched his left leg playing tennis and may have torn a muscle in his upper calf, because he afterwards noticed considerable ecchymosis. He kept about for three days, his lower leg a little swollen and painful but finally went to bed where he remained for a week. Considering himself well at the end of this time, he went about again but once more the foot became swollen and cyanotic, driving him to bed for the second time. Again he got up, again his foot became swollen and blue. Six days later I saw him. His left leg appeared normal but turned a little blue on being left dependent out of bed. There was discomfort behind the knee on forced dorsiflexion of the foot. A diagnosis of thrombosis in some of the deep veins of the great calf muscles was made.

At operation, about six weeks after the original injury, the superficial femoral vein was divided just distal to the profunda. The excised segment was not remarkable. The immediate effect of the operation was to make the foot warm and of normal color.

The patient remained in bed for a week. Then he went about, using a bandage for the second week. From this time on the leg gave less and less trouble and in six weeks following the operation the patient had ceased to notice it.

Thrombophlebitis in Varicose Veins. The fibrosed, unhealthy state of the varicose vein's wall, associated with a feeble or reversed current, is explanation enough of the common thrombosis of varix. One may presuppose infection in tissues of lowered resistance, or believe that the lining of a dilated, pocketed varicose vein actually cracks under heavy back pressure, since

pressures of arterial height have been recorded on coughing or straining. The wonder is, not that thrombosis occurs sometimes, but that it does not occur always. It usually appears near the knee, more often below than above and in a prominent dilated vessel or pocket. From its point of origin it progresses erratically upward and for an uncertain distance, but once half way up the thigh it is apt to reach the saphenous opening. Beyond this it rarely goes; that is, it rarely grows into the femoral either as a solid occluding thrombus or as a propagating clot threatening embolism.

The failure of thrombosis in a varicose vein to invade the femoral is a good example of the ending and healing of thrombosis where it encounters a strong blood stream. I know of only three instances of pulmonary infarction caused by thrombophlebitis in varix. Of these, two were successfully treated by high division of the great saphenous; the other was diagnosed only from the history and is in fact unproved. Apparently the best reason for the solid attachment of a thrombus in the great saphenous vein is again the unhealthy state of the vein's wall. This is in accord with the general principle already discussed, namely that the more outspoken the thrombophlebitis the less the danger of embolism. The dependent position of the leg—most of the time—has little to do with the confinement of the process to the varicose vein. Else the subject of varicose thrombophlebitis had better never lie down.

The thrombophlebitis of varix is occasionally acute and associated with a reddened, tender skin, local edema and some induration. Occasionally a great plaque of inflamed skin and thrombosed veins occupies the inner or posterior face of the calf. However, actual softening and suppuration is almost unknown. The process tends rather to become chronic, the thrombus remaining fixed in the vessel with little change over a period of several weeks. In the end, a combination of softening and organization occurs, by which the lumen of the vessel is restored and it regains something very much like its previous state. But once having been thrombosed, a varicose vein is always liable to a recurrence, which is a sufficient reason for dealing radically with the process.

Palliative Treatment. There are two ways of making the thrombosis of varix last a long time: the first is to go about without an elastic bandage, the second is to go to bed, sitting up with the legs outstretched in a horizontal position. Both methods keep the venous stream slow and encourage continued thrombosis. By contrast, the process is made to disappear by applying an elastic bandage and leading an active life, or, rather more effectively, by elevating the feet above the head and so remaining in bed. The first of these last two methods is especially useful when thrombosis is confined to the lower leg so that an elastoplast bandage can be firmly applied from the toes to the knee, that is, up to a point well above the level of the process. Ten days of such treatment—elastic pressure hastens the venous stream—often causes the thrombus to disappear, but of course does nothing to prevent a recurrence. Elevation of the leg in bed probably acts more quickly and has the advantage that it is equally successful when thrombophlebitis is present in the thigh. Indeed, when the process has reached the saphenous opening, it is the only satisfactory treatment.

Local applications are not essential. If any are used, heat is preferable to cold. It encourages hyperemia, brings comfort and presumably discourages further thrombosis. Whereas the traditional ice-bag retards the circulation, devitalizes the tissues and encourages an extension of the thrombus. The only good which can be said of the ice-bag is that it is often comforting, quite as much so as the hot water bottle.

Curative Treatment. To check thrombosis, shorten the patient's disability and prevent recurrence of the disease no other procedure can compare with resection of

the great saphenous vein at its entrance into the femoral. The only contraindication to the operation is the presence of a thrombus in the upper part of the vein. However, this contraindication is not absolute and in many cases it is difficult to decide before operating whether or not thrombosis has actually mounted to the saphenous opening. Should the presence of a thickened vein and local tenderness give warning that such is actually the case, the patient had better be subjected to the routine elevation of the foot of the bed. Within ten to fourteen days, the local thickening and tenderness will usually have disappeared, showing that the thrombus has been organized or liquefied. As one follows a superficial thrombosis by palpation, one is aware that the vein is becoming continually softer, so that it is less and less easily palpated. From being a solid cord, the size of a lead pencil, it will often, in a space of ten days, more or less, take on the character of a barely palpable vessel. Its wall will have become thickened, but not to such a degree as to suggest that the whole thrombus has been organized. Apparently the most clot-like portion is liquefied and carried away.

Once the upper saphena magna is again clear, it may well be resected. Opinion will naturally be divided as to when the operation should be performed. The likelihood of recurrence is such that a high division had better be made sometime. Why not, therefore, resect the vein at once and avoid a subsequent hospitalization?

Should the thrombus end proximally below the saphenous opening, the operation of dividing the great saphenous vein is performed in exactly the same way as for uncomplicated varix. One should have in mind, however, that almost every superficial thrombophlebitis is associated with some involvement of the perivenous lymphatics and some degree of lymphadenitis at the saphenous opening. Any suggestion of enlarged inflamed nodes is therefore a signal for especial care lest the glands be disturbed and spill infection into the wound. However, such an infection never seems actually to suppurate. Following high resection of the great saphenous, the thrombosis clears up very rapidly. The varicose veins as well are usually cured. Should inflamed thrombosed veins, skin and subcutaneous tissue remain after the greater part of the thrombosis has resolved, it may require a clean removal, the edges of the incision being drawn together to cover the elliptical gap.

Thrombophlebitis in Non-Varicose Superficial Veins. The form known as *phlebitis migrans* is often a complication of thromboangiitis obliterans. There it takes on its most typical appearance. However, a disease, seemingly in other respects identical, does occur in those who are not sufferers from Buerger's disease. In some of these there is a tendency to recurrence throughout life. Without any obvious cause, a stretch of vein, an inch or two in length, almost always upon the surface of the lower leg, becomes solid, thickened and slightly tender. In this state it remains for a week or two, and then, as it softens and apparently returns to something very much like its normal condition, another area of thrombophlebitis, considerably proximal to the first, appears. The first may occupy the region of the ankle, the second, the upper calf and a third, perhaps, the lower thigh. There is little tendency to embolism and continued use of an elastoplast bandage is about as successful as any other form of treatment. Whether the disease would promptly disappear (on any one occasion) if the leg were subjected to continuous elevation I do not know. It is usually treated by only partial rest and elevation and has exhausted everyone's patience before it ceases to break out.

The superficial thrombophlebitis which does not take the form of phlebitis migrans is actually more freakish and unaccountable than any other. It occurs most often perhaps in locally dilated veins which, however, are not a part of a varicose saphenous system. Local chafing, as in horseback riding, has been known to bring it on. Exposure to unusual cold, a severe

bout of coughing, a trivial injury of any sort may occasion thrombosis. It seems to have the faculty of holding on, so to speak, for considerable periods, and if not promptly cured may at any time quietly march out of a small radical into the main stem of the great saphenous and from somewhere in the course of that vessel give off an embolus. Altogether it is difficult to know whether or not to fear it. For in most cases such a thrombosis must heal with little to show for its presence. It must also be admitted that among adipose women, in whose fat a local thrombosis is not easy to identify, the diagnosis between it and a local lymphangitis or mild cellulitis must often remain doubtful.

Treatment. Following the general rule, the superficial form, if only suspected of being present, should be treated by elevation—of the legs above the head—for a period of perhaps ten days. This period is set to offer a safe margin for the cure of a thrombophlebitis not easily palpated and therefore difficult to follow clinically. As a matter of fact, I have seen it disappear completely from a vein near the ankle in less than a week. But if, as so often happens in this and other sorts, the thrombosis has already persisted for several weeks when first seen, it should receive more radical treatment. That is to say, the parent vein, usually the great saphenous, should be divided at the saphenous opening, after which the process is soon healed.

The Treatment of Minor Embolism

The treatment of such thrombophlebitis as has already caused minor embolism, that is, pulmonary infarction, offers a fascinating and difficult problem. In the case of femoro-iliac thrombophlebitis, the difficulty of determining whether a propagating clot is present and if so where it is, has already been discussed. Nevertheless there are undoubtedly occasions when the pelvis must be exposed and the attempt made, notably when septic thrombi of small size have been detached over a considerable period.

In the case of a deep thrombophlebitis among the muscles of the calf, the femoral vein distal to the profunda should be divided, a relatively simple procedure performed under local infiltration with procaine.

In the rare event of minor embolism from the varicose or non-varicose great saphenous vein, the matter is very simple, provided thrombosis does not occupy the vein at its junction with the femoral. If the saphenous can be divided above the loose clot, resection at the saphenous opening should be performed. If a serious but not fatal embolism has already occurred and there is evidence that from the fully thrombosed saphenous vein a loose clot is being propagated into the femoral, it is tempting to suppose that one can expose the common femoral above the entrance of the saphenous and while compressing the vein below the saphenous, open the femoral above. Then it should be possible to remove the clot by suction and divide the femoral, a decidedly nerve-racking procedure. If no propagating clot is found, division of the femoral vein would be less hazardous.

My own adventures have been with one instance of embolism from a thrombosis of the varicose saphenous in the mid-thigh during pregnancy, in which division at the saphenous opening was simple and curative, and with several instances of embolism supposedly from the great saphenous but in which the signs of thrombosis were no longer present. In these latter cases, exploration at the groin showed that a recent thrombophlebitis had actually occupied the great saphenous but was nearly resolved and organized; that is, the immediate danger of further embolism was over. It was then obvious that resection of the great saphenous at the femoral junction was indicated to prevent future attacks of a similar sort.

In general, my experience has led me to believe that whenever thrombosis in a

great vein, the femoral or any other, is encountered in an attempt to divide the vein proximal to the thrombosis, it is best to sever the vein through the clot. For in every case in which I have done so, a good deal of blood has been found seeping through and about the thrombus, encouraging the continued growth of its soft, friable, proximal end. I was recently faced with an instance of this sort in a patient whose heart was none too sound, and who had already suffered many pulmonary infarctions. In trying to cut off further embolism from its supposed source in the popliteal vein, I unexpectedly found the femoral thrombosed. The process could be seen to extend well into the external iliac. Finding that blood poured freely from the opened femoral vein, I divided the vessel, hoping to cut off the remaining current. Following the operation, the foot of the patient's bed was elevated 6 inches and he was encouraged to exercise his legs. No further infarctions having occurred in the following ten days, he was allowed gradually to get about and has since remained well. I cannot help attributing some part at least of the good result in this case to full division of the thrombosed vein and the subsequent encouragement of a brisk collateral circulation. Doubtless venography will in time throw further light upon this difficult subject.

REFERENCES

Aschoff, L. Lectures on Pathology, Chapter xi. New York, 1924.

Audier, M. Thromboses veineuses aiguës simulant l'embolie artérielle des membres. Paris méd., 1: 384, 1936.

Bancroft, F. W., and Stanley-Brown, Margaret. Postoperative thrombosis, thrombophlebitis and embolism. *Surg., Gynec. & Obst.*, 54: 898, 1932.

Bancroft, F. W., Stanley-Brown, M., and Quick, A. J. Postoperative thrombosis and embolism. *Am. J. Surg.*, 28: 648, 1935.

Barker, N. W. Primary idiopathic thrombophlebitis. *Arch. Int. Med.*, 58: 147, 1936.

Cruveilhier, Jean. Anatomie pathologique du corps humain. Paris, 1829–1842. Ballière. 2: Book xxvii.

Gould, E. P., and Patey, D. H. Primary thrombosis of the axillary vein—a study of 8 cases. *Brit. J. Surg.*, 16: 208, 1928.

Gregoire, R. La répercussion de l'inflammation des veines sur le système artériel collatéral. *Mém. Acad. de Chir.*, 64: 363 (Mar.) 1938.

Homans, J. The operative treatment of phlegmasia alba dolens: a preliminary report. *New England J. Med.*, 204: 1025–1032, 1931.

Homans, J. Thrombosis of the deep veins of the lower leg, causing pulmonary embolism. *New England J. Med.*, 211: 993–997, 1934.

Homans, J. Venous thrombosis in the lower limbs: its relation to pulmonary embolism. *Am. J. Surg.*, 38: 316–326, 1937.

Leriche, R. Sur l'importance de la périphlébite dans la genèse des accidents tardifs consécutifs aux oblitérations veineuses. *Bull. et mém. Soc. de Chir.*, 53: 561, 1927.

Leriche, R., and Kunlin, J. Traitement immédiat des phlébites post-opératoires par l'infiltration novocaïnique du sympathique lombaire. *Presse méd.*, 42: 1481 (part 2) 1934.

Lowenstein, P. S. Thrombosis of the axillary vein. An anatomic study. *J. A. M. A.*, 82: 854, 1924.

Maddock, W. G., and Coller, F. A. Water balance in surgery. *J. A. M. A.*, 108: 1, 1937.

Payne, R. T. Femoral thrombosis. *Lancet*, 1: 1214–1219 (May) 1938.

Dos Santos, J. C. La phlébographie directe. *J. internat. de chir.*, 3: 625 (Nov.-Dec.) 1938.

de Takats, G. Management of acute thrombophlebitic edema. *J. A. M. A.*, 100: 34, 1933.

Zimmerman, L. M., and de Takats, G. The mechanism of thrombophlebitic edema. *Arch. Surg.*, 23: 937, 1931.

THE MANAGEMENT OF ARTERIOVENOUS ANEURYSMS IN THE EXTREMITIES*

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ARTERIOVENOUS aneurysms in the extremities present so many interesting problems for clinical and laboratory investigation that much of the recent literature on this subject has been devoted almost exclusively to the pathologico-physiologic phenomena associated with abnormal communications between arteries and veins. Consequently, it has been difficult for the practicing physician and surgeon to gather from these publications the essential and practical information necessary for the efficient management of these serious surgical problems. It is our hope that, by deleting the controversal and highly scientific theories concerning these surgical lesions, we can present, in a concise form, that information which should be of immediate and practical value to those who must assume the responsibility of caring for patients with arteriovenous aneurysms in the extremities.

In this discussion we shall deal only with those arteriovenous aneurysms which result from a single communication between a large artery and a neighboring large vein. Such abnormal vascular communications are usually the result of penetrating wounds, such as gunshot or stab wounds, although occasionally a single arteriovenous communication of this type is either spontaneous or congenital in origin. From a strictly anatomic standpoint, the ordinary cirsoid aneurysms and, perhaps, many of the simple angiomas are the result of multiple abnormal communications between small arteries and veins,[1] but this great group of congenital vascular lesions rarely presents the serious clinical problems or leads to the mistakes of management which so frequently occur when the local vascular derangement is the result of a true arteriovenous aneurysm.

The *differential diagnosis* between a pulsating hematoma or false aneurysm which results from a puncture of the coats of an artery, and an acute arteriovenous aneurysm is sometimes exceedingly difficult, during the first few days after the arterial injury. The pressure from a large hematoma at the site of injury of large blood vessels may obscure all of the classical signs and symptoms of an abnormal arteriovenous communication. It may be several days before the appearance of the characteristic thrill and bruit.

In the case of an unimpeded arteriovenous fistula, the characteristic to and fro murmur with a marked intensification initiated by systole of the heart, cannot fail to be elicited by simple auscultation over the injured area. Palpation over the same area always gives the unmistakable continuous thrill produced by the rapid passage of arterial blood through the abnormal communication into the vein. The marked alteration of the local venous pressure usually produces enlargement and tortuosity of the superficial veins of the extremity. These changes in the veins first take place in the region of the injury to the vessels, but later may involve other veins throughout the affected extremity. (Fig. 1.) The intravascular pressure changes in these superficial varicosities are usually so pronounced that the veins actually pulsate with each inrush of blood from the injured artery into the injured vein.

The *pathologic-physiology* of such abnormal communication between arteries and veins must be thoroughly understood if the most effective treatment is to be out-

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lined for any given patient. The effects of arteriovenous aneurysms are usually limited to the site of trauma during the

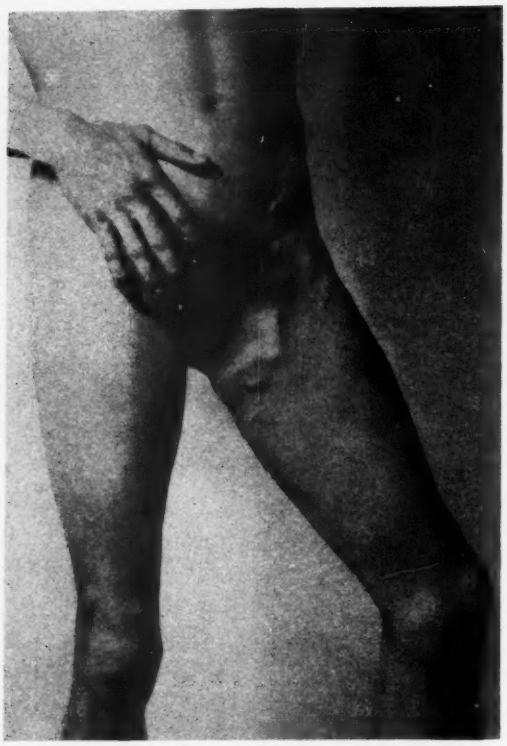

Fig. 1. Showing the dilatation and tortuosity of the superficial veins in the region of an arteriovenous aneurysm.

first few hours or days following the injury but in certain rare instances the added work upon the heart causes such serious cardiac embarrassment that immediate surgical intervention is necessary to save the patient's life. Mason,[2] Stone, and others have described acute cardiac dilatation due to the sudden shunting of large quantities of arterial blood into great veins and thence into the right side of the heart. This immediate complication is rare, but it is of such great importance that the attending physician or surgeon must constantly keep it in mind. Clinically the occurrence of tachycardia, dyspnea, peripheral edema and marked enlargement of the heart should lead one to suspect this complication.

The loss of considerable blood to the exterior from the penetrating wound is frequently alarming to the patient, but rarely requires any special operation to control the hemorrhage. The elevation of the extremity with the application of the finger or a piece of sterile gauze over the wound in the skin is frequently all that is necessary to control the external bleeding. If considerable loss of blood takes place before the patient is seen by the physician or surgeon or before first aid can be given, it is then frequently necessary to restore the blood volume to an adequate level by the intravenous administration of normal saline solution or 5 per cent glucose solution and the transfusion of whole blood from a suitable donor before any further treatment is instituted.

Bleeding into the tissues of the extremity should be considered a more serious complication. The infiltration of the muscles with blood may continue until the pressure within the extremity becomes so great that the flow of blood through the collateral arteries is partially or completely cut off and serious ischemia of the distal portions of the extremity results. Such ischemia may be so complete that early gangrene of the distal part of the extremity takes place. Under such circumstances it may also be necessary to resort to operative treatment of the area to reduce this compression of the essential collateral arteries.

The development of signs of inflammation in the hematoma or in the damaged tissue about the arteriovenous aneurysm must be considered as a serious complication. Bacteria grow rapidly in this ideal culture medium and extensive suppuration usually leads to massive secondary hemorrhage through the external wound. If, therefore, definite signs of infection are present in and about the injured area, there is more risk to the patient's life in delaying active treatment with the hope that the infection will subside, than there is in immediately carrying out the necessary surgical treatment.

As the abnormal communication between the artery and vein becomes more permanently established, other changes in the dynamics of the circulation begin to

take place. These so-called *late effects* must constantly be borne in mind by the attending physician lest the optimum time for the performance of the curative surgical procedure will pass unrecognized and the myocardial damage will become so great that it enormously increases the risk of surgical intervention.

The pressure of the blood within the peripheral veins distal to the arteriovenous fistula is usually greatly elevated due to the increase in the resistance to the return flow of venous blood caused by the shunting of arterial blood into one of the large veins of an extremity. Such a rise in the peripheral venous pressure also occurs when a large hematoma or even a large arterial aneurysm presses upon one of the major veins of an extremity; consequently, a mere elevation of the peripheral venous pressure does not necessarily indicate the presence of an arteriovenous aneurysm. We feel, however, that a rise in the general venous pressure, as for example the elevation of the venous pressure in the arm when an abnormal arteriovenous communication of long standing is situated in the leg, should be considered of definite significance since it usually means that the added work which the arteriovenous aneurysm has thrown upon the heart has resulted in cardiac decompensation. We believe that there is usually no significant increase in the general venous pressure until there begins to be definite embarrassment of the cardiac function.

The changes in the systolic blood pressure are usually less marked but may be of distinct value in estimating the amount of added work which has been thrown upon the heart as the result of the arteriovenous communication. The ordinary blood pressure readings in the arm under such conditions are apparently within the normal range when the arteriovenous communication is located in the leg or in the opposite arm, but if the blood pressure is taken while the arteriovenous communication is temporarily occluded by external pressure, there is frequently a striking and rapid rise in the systemic blood pressure. We regard this as an important clinical observation and the rate and degree of the rise of the blood pressure seems to bear direct relation to the extra work which has been placed upon the heart as the result of the arteriovenous communication.

The efficiency of the arterial circulation distal to the fistula may be greatly reduced. This subacute ischemia which occurs as a late complication to an abnormal arteriovenous communication rarely leads to frank gangrene of any of the distal portions of the extremity. It is not uncommon, however, to find that the interference with the nutrition of the muscles is so great that classical intermittent claudication develops after relatively slight exertion.

The associated dilatation of the superficial veins together with subacute or chronic ischemia of the extremity may also lead to the formation of chronic ulcers of the lower leg or ankle. These chronic ulcers are usually very resistant to treatment and due to the fact that they are surrounded by dilated blood vessels, it is not uncommon for profuse bleeding to take place after slight traumatization. The subacute ischemia of the distal portion of an affected extremity usually causes the skin of the foot to be paler and colder than the normal foot. Frequently, it is impossible to palpate a pulse in the pedal arteries when the abnormal arteriovenous communication is between the femoral vessels of that extremity.

However, the presence of an arteriovenous aneurysm is a powerful stimulus to the development of a collateral arterial circulation in an affected extremity. It has been frequently demonstrated that during a period of four to six months after the establishment of an abnormal arteriovenous communication, there develops around this fistula, a collateral arterial circulation which is much greater than that which develops after simple ligation of the artery. When this collateral arterial circulation is once developed it is possible for the surgeon to carry out almost any opera-

tion necessary to close the communication between the artery and the vein even to the point of completely excising the portions of both the artery and vein which contain the fistula.

When an arteriovenous aneurysm occurs in the extremity of a growing individual, there is occasionally an actual lengthening of the extremity due to the increased vascularity about the growth center of the long bones. This same type of stimulation of local growth of bone may be associated with other diseases such as osteomyelitis and is, therefore, not pathognomonic of arteriovenous aneurysm.

The most important *effects* of a long standing arteriovenous aneurysm in an extremity are those which result from the added work upon the heart. The position and the size of the fistula between the artery and the vein determine to a great degree the amount of arterial blood which is thrown back upon the right side of the heart. During the early stages, the heart may compensate remarkably for this added strain but when the strain continues to act over a long period of time, there is definite enlargement of the heart due principally to hypertrophy and dilatation of the right ventricle. Such patients usually give a story of increasing dyspnea which has slowly come on over a period of weeks or months and an inability to take part in any competitive games due to easy fatigability. In the later stages, gross irregularity of the cardiac action may be observed by the patient or his physician.

In patients in whom the abnormal arteriovenous communication has been present for many weeks or months, it is frequently possible to get some advance notion concerning the added burden which has been thrown upon the heart by observing the degree of slowing of the heart action when the communication between the artery and the vein is temporarily occluded by digital pressure. This phenomenon, which is known as Branham's bradycardiac sign, is considered important evidence that the heart is being subjected to an abnormal degree of strain as the result of an arteriovenous aneurysm.

The *pathologic changes* which take place in the vessels about the arteriovenous aneurysm are of great importance to the surgeon. The portion of the major artery just proximal to the arteriovenous fistula frequently becomes greatly enlarged and sometimes quite tortuous. The wall of this artery becomes very thin and takes on the anatomic characteristics of the vein. This structural change has been described by Holman[3] as "venification" of the artery. At the same time that the artery undergoes these changes, the major vein or veins which take part in the arteriovenous aneurysm become enlarged, but their walls become considerably thickened. This structural change Holman describes as "arterialization" of the vein. These changes in the vessels are undoubtedly the result of the great alterations in the local pressure within these blood vessels due to shunting of blood from the major artery directly into the major vein. In long standing arteriovenous aneurysms of the extremities, it is rare to find serious damage to the heart without marked dilatation of the artery proximal to the fistula.

SURGICAL TREATMENT

During the evolution of an arteriovenous aneurysm from the time of the original traumatization of an artery and a vein in an extremity to the late stages associated with serious cardiac damage, there may be many different indications for surgical intervention either as emergency or life-saving procedures or as elective and curative surgical operations.

Massive hemorrhage into the tissues of an extremity or the formation of a large hematoma may occur as an early complication of such vascular injuries. The compression of collateral arterial pathways in such an extremity may be so complete that the nutrition of the tissues distal to the injured vessels is seriously impaired. Early surgical operation with the evacuation of

all clots of blood should be carried out to relieve as much tension as possible on the vital structures of that extremity. The use of a tourniquet on the proximal side of the injury to the great vessels is usually necessary and a large incision in the skin and superficial tissues is recommended to provide an adequate exposure of the injured vessels. After all clots of blood have been washed out of the wound by careful irrigation with warm saline solution, the glistening intima of the injured artery is usually detected without difficulty.

If the wound in the artery is small and the edges are not seriously damaged it may be possible to restore continuity by the use of interrupted sutures of fine silk placed near each other. All clots of blood in and about the injured artery must be removed before any attempt is made to reconstruct it. It is also important to reinforce the suture line in the injured artery with a small flap of vein. The injured major vein should be ligated above and below the point of rupture of its wall and no attempt should ever be made to restore its continuity.

After all the bleeding has been controlled, the skin and superficial tissues external to the fascia should be brought together loosely by widely spaced interrupted sutures. A sterile gauze sponge moistened with warm saline solution should be placed directly on the sutured wound and the entire area then covered with some waterproof material to retard the desiccation of the wound and the dressing. The capillary action of the saline solution within the meshes of the gauze sponge helps to draw the old blood and serum out of the wound through the space between the sutures.

In those cases in which the artery has been completely severed, it is usually unwise to attempt to restore its continuity by suturing together the injured ends of the vessel. When the injury to the artery is so extensive we believe that the proximal and distal ends should be isolated carefully and then ligated with heavy braided silk or narrow cotton tape. The choice of the suture material and its size should be governed by the caliber and activity of the artery which is to be ligated.[4] If the surgeon is skilled in the use of the Tuffier tubes it may be possible to restore the blood-carrying function of an injured artery for a sufficient length of time to permit the spontaneous development of an adequate collateral arterial circulation in the affected extremity. After an artery has been repaired by sutures or after the continuity of the injured artery has been restored by the insertion of a Tuffier tube, it may be wise to prevent further intravascular clotting of blood from taking place by the administration of purified heparin according to the method suggested by Murray, Best and their associates[5] in Toronto.

Since we also have available an active means of stimulating the flow of blood through existing collateral arterial pathways by the rhythmic alternation of the environmental pressure about an extremity in the form of passive vascular exercises,[6] we have ceased to worry about severe degrees of ischemia which occasionally make their appearance after these extensive surgical operations upon the vascular system. If the need arises we can usually restore the arterial circulation to an adequate level by this physical means and thus prevent the occurrence of degenerative changes in the distal part of the affected extremity. When the small arterial and arteriolar network is structurally normal only a few days of intensive passive vascular exercise treatment are necessary to get the flow of blood started through the existing collateral arterial pathways. This method of overcoming acute ischemia of the tissues distal to the injured vessels of an extremity must be considered as a valuable adjuvant and should be kept ready for immediate use during the active phase of surgical treatment. It has given us the added courage necessary to perform very radical surgical procedures upon the peripheral vascular system when such operations are absolutely

necessary for the cure of the arteriovenous aneurysms.

In those acute cases where a tourniquet cannot be applied proximally to the injury of the vessels, it is essential that some form of temporary occlusion of the major artery proximal to the aneurysm be performed before any attempt is made to cut into the aneurysm. Severe hemorrhage may result even when the incoming artery is temporarily occluded but the bleeding can usually be controlled by digital pressure after the clots of blood are rapidly removed from the wound. The ligation of the incoming artery should *never* be employed as a means of giving permanent relief. This proximal occlusion of the artery interferes greatly with the collateral arterial circulation and it is almost certain to lead to gangrene of some distal part of the extremity. The injured artery should be ligated immediately above and below the injured area in order to preserve as many of the collateral arteries as possible.

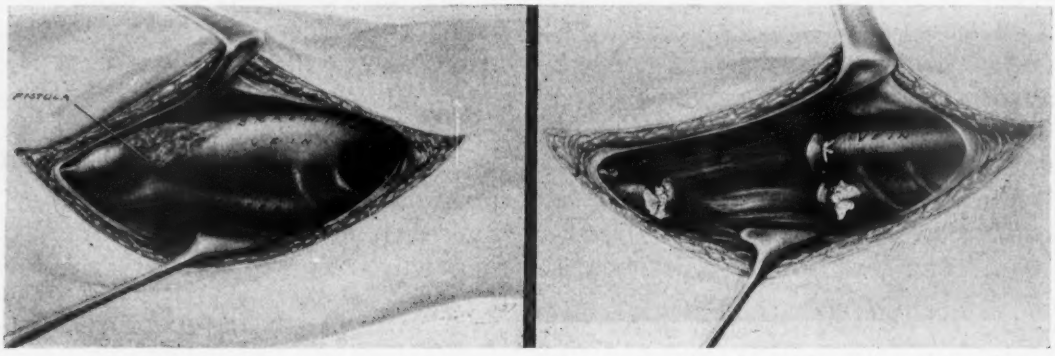

Fig. 2. Dissection of the arteriovenous aneurysm and method of ligation and excision of the abnormal communication between the brachial artery and the brachial vein.

An emergency surgical operation is indicated if signs of infection make their appearance in the hematoma about the injured vessels. Experience has shown that delay in these cases may lead to massive secondary hemorrhage which is usually very difficult to control. The operation is performed exactly as we have already described for the treatment of massive hematoma about injured vessels, except that no attempt should be made to close the wound when infection is present. We believe that braided silk sutures or tape should be used to ligate the major vessels even in the presence of infection and we prefer to leave these ligatures completely exposed at the bottom of the wound where they will receive the same cleansing treatment which is given to the rest of the wound. The proper and judicious use of Dakin's solution after the first few days usually hastens the process of healing and does not contribute to the danger of secondary hemorrhage. With careful irrigation and dakinization of the wound, the healing processes usually take place without great delay and often without the need of removing the large silk ligatures which were used to occlude the major arteries at the bottom of the wound.

Occasionally an emergency operation must be performed upon the arteriovenous aneurysm because the patient is showing signs of acute cardiac decompensation. Such a patient will rarely tolerate any extensive operative procedure and the simplest operation which will remove the majority of the strain from the heart, should be done without delay. The simple ligation of the involved vein at a point 2 or 3 inches proximal to the arteriovenous fistula, usually gives a satisfactory degree of immediate relief. At some later time when the patient's heart is in better condition, the curative surgical operation can be carried out without undue technical difficulty.

In those patients in whom the arteriovenous aneurysm has been present for many months or years we believe that the

best chance for complete cure will result from excision of the involved artery and the involved vein together with the removal

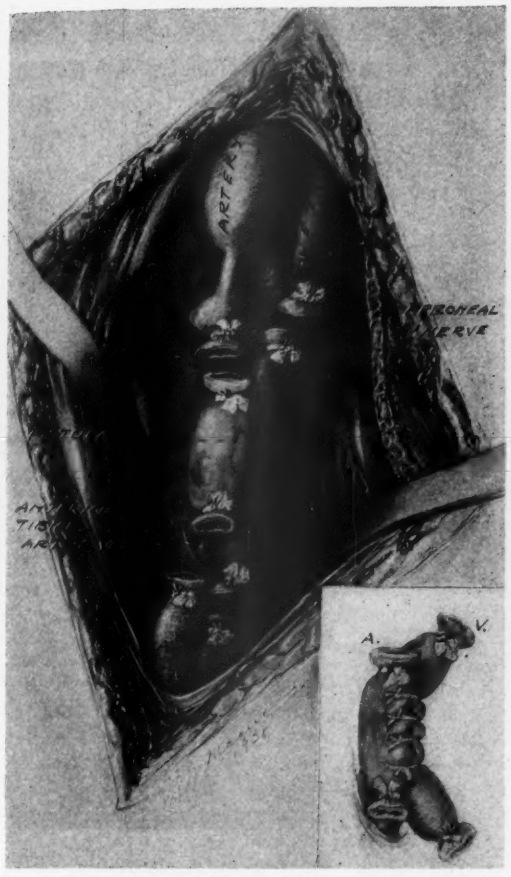

Fig. 3. Quadruple ligation of the major vessels involved in an arteriovenous aneurysm. The method of occluding the fistula is shown in detail.

of the section where the two vessels communicate with each other. (Fig. 2.)

In other patients it may not be possible to free completely the site of the fistula, but under such circumstances the quadruple ligation of the involved vessels and all of the anastomosing branches will effect a complete cure of the aneurysm. However, after the ligation of all of these vessels, it is advisable, in case a branch has been overlooked, to occlude permanently the communication between the vessels by interrupted through-and-through sutures of braided silk. (Fig. 3.) Occasionally the fistula is so located that it is technically too difficult or dangerous to attempt to ligate all branches of the involved vessels. In such instances the proximal and distal ligation of the artery is first performed and then transfixion occluding sutures of

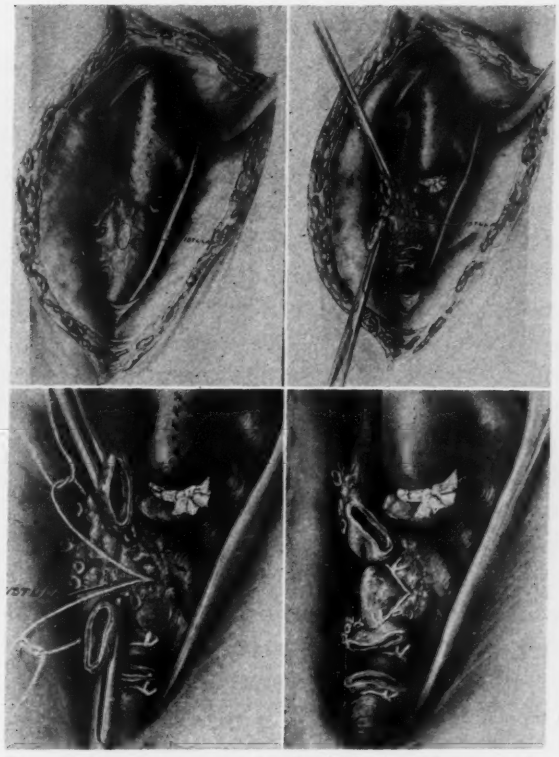

Fig. 4. Successive steps in the isolation of an arteriovenous aneurysm and the method of closing the abnormal communication between the artery and vein by means of the transfixion occluding sutures.

braided silk are placed in such a way as completely to occlude the fistula. (Fig. 4.) This procedure will also result in a complete cure of the arteriovenous aneurysm.

In young adults in whom the arteriovenous aneurysm has not existed long enough to produce the characteristic structural changes in the involved artery and vein it may be desirable to restore the continuity of the artery. This can be accomplished by exposing the fistula through an opening in the opposite side of the involved vein. This transvenous approach, as described by Rudolph Matas,[7] permits the surgeon to repair the opening in the artery and then reinforce the suture line with viable flaps from the vein. Attempts to reconstruct the vein may result in pulmonary embolism, and therefore the procedure should be discouraged.

REMARKS

The most essential fact concerning the elective operations for arteriovenous aneurysm is the absolute necessity of doing some surgical procedure which will completely prevent blood from passing through the fistula from the artery into the vein. In general, any operation which does not accomplish the occlusion of the abnormal communication will certainly not be a permanent cure of the aneurysm. We cannot condemn too strongly the procedure of simple ligation of the involved artery at any point proximal to the fistula. This operation is still commonly used in spite of the fact that it carries with it a high incidence of gangrene of the affected extremity. The procedure simply cuts off the main force of the arterial stream so that the small amount of arterial blood which finds its way around the collateral arterial pathways into the distal portion of the major artery immediately takes the path of least resistance by passing through the fistula and back to the heart, thus depriving the rest of the extremity of its proper nourishment.

We prefer to allow a period of from four to six months to elapse before performing any elective operations for the cure of arteriovenous aneurysms in the extremities since experience has shown that the collateral arterial circulation which develops spontaneously will greatly reduce the risks of complication resulting from serious arterial insufficiency in the distal parts of the affected extremity. This delay also permits the extravasated blood to become completely absorbed and the tissues to return to a more or less healthy condition and appearance, thereby greatly reducing the probability of stirring up any old infection in the wound. When all of these dangers are removed the surgeon can freely choose from the numerous curative surgical operations that one which is best suited to his particular case and carry out the procedure without any fear that some serious complication will eradicate all his hopes for success. It is well to remember, however, that the surgical operations upon arteriovenous aneurysms are frequently very difficult and usually demand the greatest surgical skill, linked with sound surgical judgment. The execution of such operative procedures should not be attempted by any surgeon who has not had considerable experience with the suturing and ligation of large blood vessels.

REFERENCES

1. Reid, Mont R. Studies of abnormal arteriovenous communications, acquired and congenital. *Arch. Surg.*, 10: 601, 1925; 10: 996, 1925; 11: 25, 1925; 11: 237, 1925; *Ann. Surg.*, 108: 642, 1938.
2. Mason, J. M. Extreme cardiac decompensation following traumatic arteriovenous fistula of the left subclavian vessels. *Am. J. Surg.*, 20: 451, 1933; *Tr. Soutb. Surg. A.*, 45: 282, 1932.
3. Holman, Emile. Arteriovenous Aneurysms. New York, 1937. Macmillan Company.
4. Reid, Mont R. The ligation of large arteries. *Surg., Gynec. & Obst.*, 58: 287, 1934.
5. Murray, D. W. G., Jaques, L. B., Perrett, T. S., and Best, C. H. Heparin and the thrombosis of veins following injury. *Surgery*, 2: 163, 1937; *J. A. M. A.*, 110: 118, 1938.
6. Herrmann, Louis G. Passive Vascular Exercises. Philadelphia, 1936. J. B. Lippincott.
7. Matas, Rudolph. Diseases of the Vascular System. In Keen's Surgery, vol. 5, Chapter 70, 1909.

ACUTE ARTERIAL OCCLUSION OF THE EXTREMITIES*

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ACUTE occlusion of the peripheral arteries, although infrequent, occurs often enough to warrant keeping it in mind since suspecting it leads us to the examination which will furnish the diagnosis. This fact and the report of three additional cases constitute the justification for this review.

Pathology. Most authors agree that acute occlusion of a peripheral artery is the result of an embolus originating elsewhere. Occasionally[1] attempts are made to distinguish between embolism and acute thrombosis, but such differentiation is admittedly extremely inaccurate. Although thrombosis can occur, the process usually is so gradual as to allow the development of sufficient collateral circulation to prevent gangrene or even the acute symptoms which ordinarily are ascribed to sudden occlusion.

To lodge in the peripheral arteries, emboli must originate in the left heart, the arteries proximal to the site of lodgment, or the pulmonary veins. The great majority come from the left heart.[3] Most of the cases reported had suffered from myocardial disease and irregular rhythm and the occurrence of embolus not infrequently followed shortly after the reëstablishment of normal rhythm, suggesting that a clot formed in the left auricle was expelled by the more vigorous and efficient contractions occurring with normal rhythm. Under this heading should be considered also paradoxical emboli which originate in the systemic veins and, due to a patent foramen ovale, cross the intraventricular septum, to be distributed in the systemic arteries instead of following the normal course from the right ventricle to the pulmonary arteries. This type is extremely rare because of the low percentage of patent foramina.

The site of lodgment is almost entirely at some point of rapid diminution in the size of the artery and, because this rarely occurs except at a division of the vessel, one usually finds the block to be at one of the main divisions of the peripheral artery such as the transformation of the brachial into the radial and ulnar or the division of the common femoral into the profunda and superficialis, the division of the popliteal into the anterior and posterior tibials, et cetera. This knowledge is extremely helpful in localization of the block.

The consistency of the clot has considerable influence upon the effects. A firmly organized, fairly old, embolus tends to lodge firmly and to remain intact. This frequently allows collaterals distal to the block to maintain sufficient circulation to the periphery. A younger and softer embolus, on the other hand, may break up when it strikes a bifurcation and descend along the branches as several small emboli, thus blocking numerous small and terminal branches. This is much more likely to produce gangrene than the former type. In many cases, lodgment of an embolus is frequently followed by thrombosis extending from the embolus distally and, on occasion, even proximally. The thrombosis blocks more and more of the collaterals with increasing disturbance of the nutrition of the part.

With the occurrence of any embolic lodgment there is almost invariably more or less degree of spasm affecting the arteries supplied by the occluded vessel. This is often extreme and greatly diminishes what might otherwise be an adequate collateral circulation. It persists for a variable period,

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often twenty-four to forty-eight hours. This mechanism furnishes the rationale for the use of antispasmodics, such as papaverine, and accounts for the beneficial results frequently obtained when they are administered.

When embolism occurs in the peripheral arteries, the intima in contact with the embolus undergoes change, sometimes within two to three hours and occasionally not for twelve hours or more. If undisturbed, this process extends to such a degree that, even though the embolus be removed, thrombosis will immediately follow and again occlude the vessel. This accounts for the failure of surgical removal in late cases and even in some of the earlier ones.

One cannot overlook the importance of certain other considerations such as the elasticity of the vessels involved, the efficiency of the general circulation and interference with collaterals by previous pathology or anatomic variation.

Symptomatology. In the great majority of patients the disease is initiated by sudden, severe pain in the involved extremity. In a few there is gradually increasing pain or numbness of the extremity followed by pain. Occasionally there is no complaint of pain at any time. Practically all of the patients complain of extreme numbness of the extremity. Most of them have weakness or paralysis of muscles and a cold skin in the involved area. Upon examination the oustanding features are pallor, decreased skin temperature easily determined by the palpating hand, partial or complete anesthesia, absence of skin and tendon reflexes, and the extremely important absence of pulsation in the vessel distal to the occlusion. With the onset of gangrene pain is ameliorated.

Localization. Of necessity the evidence of ischemia will not extend proximally as far as the embolus since the branches arising proximal to the occlusion will supply the superficial tissues for a variable space. Thus a block of the femoral just below the profunda will cause little or no disturbance of sensation, color, warmth, or function of the thigh, but will affect mainly the leg and foot from the knee downward and no pulsation can be felt in the popliteal. However, when the vessel under question is sufficiently superficial, as the brachial and axillary, one can determine by palpation the exact point where pulsation ceases. Also at this point one usually feels a firm and slight enlargement of the vessel.

Another helpful method suggested by Linton[2] is the application of a blood pressure cuff to the extremity at various levels. The indicator needle will show a definite oscillation above and little or none below the point of obstruction. Thus by shifting the cuff up and down the extremity one may obtain a fairly accurate localization. Unfortunately many lesions occur so near the trunk that this method cannot be applied. Arteriography has been utilized in a few instances to determine the location of the embolus when it could not otherwise be easily found.[3]

Treatment. From a limited experience and a study of the literature it appears that the best results are derived from (1) early diagnosis before ischemia produces irreparable harm; (2) abolition of spasm; (3) extraction of the clot or arteriectomy; (4) passive vascular exercise for increasing collateral circulation; and (5) protection of devitalized tissue from immoderate heat and from further deprivation of blood by elevation.

Antispasmodics. Since the degree of associated spasm is often surprisingly great, diminution or abolition of it frequently prevents gangrene and may allow restoration of normal function in spite of the persisting embolic occlusion. Although sympathectomy has been suggested it is a serious operation for such an ill patient and its good effects cannot be accurately forecast. General or spinal anesthesia add an additional load to an already ill patient and cannot be indefinitely prolonged.

Antispasmodics, such as papaverine and eupaverine, are equally effective, quicker in action, more simple and apparently nontoxic. They can be used to determine

quickly the degree of spasm and should be effective within a half hour. If, because of blockade of collaterals, extreme arteriosclerosis, etc., no immediate improvement is apparent, very little time is wasted and more radical methods can be adopted while they still may be helpful. Papaverine, gr. ¼ to ½ intravenously should be given and, if the circulation returns to the part, should be repeated three or four times daily for four days or more. Denk[4] reports that in seventeen out of twenty-five extremities so treated recovery ensued without gangrene and that seven out of nine patients with pulmonary embolism survived. Using papaverine de Takats[5] saw rather dramatic improvement in five of six cases, including one instance of serious pulmonary embolism. In one the leg recovered under the administration of antispasmodics after passive vascular exercise had failed. Other individual case reports are suggestive.

Embolectomy. If circulation is not satisfactory within two hours after the use of antispasmodics the situation should be considered a surgical emergency and immediate operation done. If twelve hours or more have elapsed since onset, embolectomy will probably not be successful but occasional recovery has been reported after as much as forty-eight hours.[4] Accurate localization, the Carrell technique, local anesthesia, and gentle extraction of the clot without intimal damage often lead to the reëstablishment of the flow through the artery.

TABLE I
EMBOLECTOMY

Author	Number of Extremities	Extremity	Recovered without Gangrene	Indeterminate (Died too soon)
Linton[2] (44 cases)	12	Axillary..... 1 Iliac, femoral, and popliteal. 10 Aorta..... 1	1 3 0	 3
Lund[3] (55 cases)	30	Arm..... 7 Leg.....23	6 9	0 4
Pearse[3] (282 cases)	282	Arm.....46 Leg.....205 Aorta.....31	20 58 7	
Key[4] (43 cases)	48	Arm..... 4 Leg.....42 Aorta..... 2	4 14 (6 showed good local effect but died)	20 1 gangrene (good localization)

TABLE II
SYMPTOMATIC TREATMENT

Author	Number of Extremities	Extremity	Recovered	Indeterminate (Died too soon)
Linton[2] (44 cases)	18	Arm..... 5 Leg.....13	4 1	
Lund[3] (55 cases)	30 (without operation; other treatment not specified)	Arm..... 7 Leg.....23	5 4	2 3

TABLE III
PASSIVE VASCULAR EXERCISE

Author	Number of Extremities	Extremity	Recovered without Gangrene	Indeterminate (Died too soon)
Linton.[2] Negative element alone: 2 out of 6 extremities recovered. Negative-Positive: 7 out of 9 extremities recovered.	15	Aorta..... 6 Iliac, femoral, and popliteal. 9	3 6	2 1
de Takats[5]	3	Leg..... 3	0	
Hermann and Reid[6]	10		10	

Table I gives an idea of the recoveries in some 500 cases. It is evident that the legs are much more likely than the arms to become gangrenous when major vessels are obstructed. In fact, a few observers suggest that it is unnecessary to operate upon axillary or brachial occlusion.

Reference to Table II, concerning symptomatic treatment only, shows a high percentage of recoveries without operation and apparently without antispasmodics or vascular exercise. However, it is logical that effective methods applied early should improve this percentage even in the arms which are so favored anatomically. The

major difficulty in comparative statistics here is the high mortality among these patients from the original pathology, such as heart disease, or from associated emboli to vital organs as the brain, kidney, etc., death often occurring before results of treatment to the extremities can be evaluated.

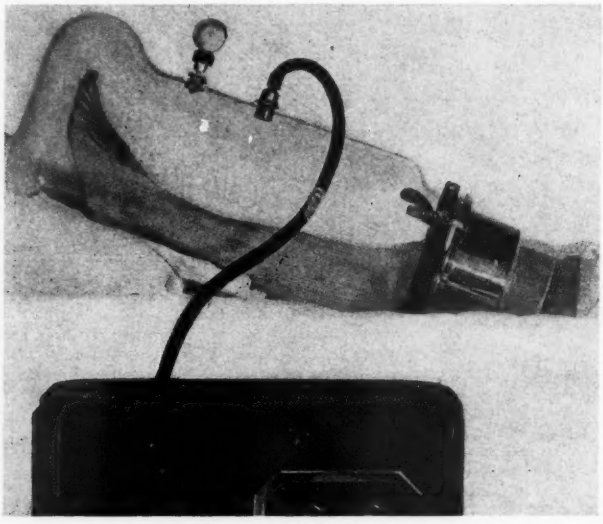

Fig. 1. Pavaex in use.

Passive Vascular Exercise. This has been reintroduced and modernized by Hermann and Reid[6] and Landis and Gibbon.[7] It produces definite improvement in most cases of such inadequate circulation and frequently prevents gangrene. Table III summarizes some available reports. If immediate treatment by antispasmodics and/or embolectomy is not successful, or if the patient is seen too late for their use, the pavaex treatment of alternate negative and positive pressure is definitely indicated and extremely beneficial. Hermann and Reid advise slow oscillation of from 40 mm. of mercury positive to 80 mm. of negative pressure with four cycles per minute, five of each fifteen seconds of a cycle for the positive and ten seconds for the negative phase. An additional substratum of short oscillation occurring eighty to one-hundred times per minute throughout both phases is included in the apparatus designed by Hermann.[6] The treatments are from one-half to two hours and should be given several times a day. According to these authors "there seems to be no limit to the time the treatment can be carried out without discomfort or untoward effects."

Arteriectomy has recently been advocated by Leriche.[9] Since ligation of a vessel at any given point is much less likely to produce gangrene than embolus to the same point, the thought is to excise the segment of the artery so damaged by the lodgment of an embolus that thrombosis follows its extraction. This author feels that an excision of the involved portion of the vessel with ligation of the adjacent remnants will substitute ligation with its lessened danger of gangrene for thrombosis with its associated spasm and likelihood of propagation of the clot. He reports one such case with recovery in six hours after arteriectomy.

One must not forget that considerable harm may ensue from elevation of the extremity affected by arterial occlusion, allowing rapid return of the blood through the unobstructed veins and further increasing the ischemia; that tissues deprived of blood supply are easily damaged by temperatures above 100 degrees and that delay in applying appropriate treatment greatly decreases the chance for recovery of the part.

CASE REPORTS

Case 1. Mrs. I. S., age 47 years, was admitted October 31, 1935 because of cardiac failure with auricular fibrillation, the result of rheumatic heart disease from which she had suffered for the previous fourteen years. She was dyspneic and her legs were immensely swollen. Weakness and severe precordial pain were also present. Examination revealed a marked degree of arteriosclerosis, an enlarged fibrillating heart with extensive evidence of myocardial failure. Laboratory studies revealed no diabetes, a negative Wassermann, and a normal blood count except for a leucocytosis to 17,000 with 80 per cent polymorphonuclears of which 28 were non-filamented.

Slightly over two weeks later, at approximately noon, she was suddenly seized with precordial pain and almost simultaneously with severe pain in the left arm and hand; a few minutes later severe pain also appeared in the right hand and arm. The hands were blanched, cool, and no pulsation could be found in the arteries of the vessels of either arm, on the right below the axilla and on the left below the mid-brachial areas. Morphine sulphate, gr. ⅓ and nitroglycerine and amyl nitrite relieved the substernal but not the brachial pain. However, she became comfortable in the next two hours and the color and warmth partially returned to the hands although no pulsations could be felt in the vessels. At 5 o'clock in the afternoon pain returned and both hands and forearms became cyanosed and cold.

She was seen at this time in consultation and, although some five and one-half hours had elapsed since onset, embolectomy was advised. This was done immediately, approximately six hours after the onset. Under local anesthesia the right axilla was opened over the point where the pulsation ceased and, with the Carrell technique, the artery was opened and a firm, slightly adherent, clot was removed. A good flow of blood was obtained proximally but only a slight flow distally. The intima was somewhat discolored and roughened. The artery was closed and compression released and for a few seconds pulsations could be palpated in the brachial though none reached the radial at the wrist. After about sixty seconds pulsations gradually ceased and although sutures were removed and another soft clot extracted the same thrombotic result again occurred. The left brachial was exposed midway between the shoulder and elbow where pulsation ceased and a high division of the brachial into the radial and ulnar branches was discovered at this point. There was a hemorrhagic band about 2 cm. wide at the bifurcation, below which no pulsations were noted. The vertical incision was made and a rather firm clot, somewhat adherent to the intima extending down into the radial for 2.5 cm., was extracted. Again, when the artery was closed and the compression released pulsations could be palpated in the radial at the wrist for sixty to eighty seconds, following which they disappeared. The artery was reopened and the clot again removed with the same result. Postoperatively both hands were fairly warm but no pulsation of the distal vessels could be discerned on either side.

For the next two days the arms and hands continued to have a fair color and, with the assistance of external heat, a moderate amount of warmth. At this time, in the absence of suitable pavaex apparatus, the arms were alternately inserted into the Drinker respirator for babies, the right arm being given treatment for two hours and the left for one hour out of every three.

Four days postoperatively, the color and warmth of both hands were greatly improved and on the left were practically normal. On this side a radial pulse could be felt though none was present on the right. However, the patient was able to move the right hand though she still complained of slight pain in this arm. This pain disappeared in the next three days, but pulsations did not return to the right radial up to the date of discharge December 15, 1935, twenty-seven days after operation.

Alternate suction and pressure were continued in the out-patient department. The right pulse became perceptible first on April 8, 1936, almost six months postoperatively. Meanwhile the patient experienced decreased sensation in the right hand which gradually was reduced to the fourth and fifth fingers by July.

Additional occurrences of significance consisted of a transient hemiplegia in January, 1937 and another more severe attack the following December. The woman was last seen on January 5, 1939, with good circulation in both arms, good pulsations in the left arm,

poor in the right, and partial recovery from her hemiplegia.

Case II. A boy of 10 (F. W.), was admitted June 25, 1937 with acute osteomyelitis of the left femur and left humerus and staphylococcus septicemia. He was seen in consultation on July 3 because of cyanosis, loss of normal warmth and pulsation on the left forearm, occurring after incision and drainage of osteomyelitis of the left humerus. The brachial pulse could be felt down to the antecubital space, at which point it disappeared and a slightly firm enlargement of the artery could be felt. Operation was advised and embolectomy was done by the Carrell technique, approximately three hours after onset. Pulsation of the radial and ulnar followed release of the compression for about two minutes, but then decreased and disappeared.

Passive vascular exercise was applied immediately after operation and some improvement could be noted in the course of the next twelve hours.

In spite of blood transfusion, bacteriophage, staphylococcus antitoxin in large doses, and supportive measures, the patient died four days after the occurrence of the embolus. With intermittent use of passive vascular exercise the circulation of the left arm improved for three and one-half days although pulsations did not return. For the last eight to ten hours before death from the septicemia and multiple new foci in other bones, joints and the kidneys, the circulation of his arm again showed signs of failing, possibly due to the general circulatory collapse, although it was more marked in the left arm and hand than in the other extremities. However, no gangrene had occurred at the time of death, as proved by post-mortem examination.

Case III. P. C., a woman of 47 years, was admitted March 34, 1938 on the Service of Dr. W. W. Babcock. She had suffered for twenty years with rheumatic heart disease with frequent attacks of fibrillation and on one occasion there was evidence of left cerebral and splenic infarction. Seven and one-half hours before admission she had suddenly developed terrific pain in the pelvis and lower extremities which later became paralyzed. Examination showed the lower extremities to be anesthetic and cold, and the vessels were considered to be moribund. Immediate operation was done by Dr. Babcock, opening both femoral arteries to remove by retrograde extraction the clot that was straddling the bifurcation of the aorta. However, a very weak flow of blood on the right and a moderate flow on the left were the best that could be obtained. When the arteries were closed, pulsations rapidly diminished and ceased by the time the wounds were sutured.

In the course of the next thirty-eight hours the legs became increasingly mottled and dark, bullae formed over the skin, and gangrene was apparently impending. The patient expired thirty-eight hours after operation. No autopsy was granted.

SUMMARY

1. A brief review of acute arterial occlusion of the extremities is presented.

2. Recent advances in treatment are outlined and compared statistically.

3. Three cases of arterial embolus, one of them simultaneously bilateral, are presented.

REFERENCES

1. McKechnie, R. E., and Allen, E. V. Sudden occlusion of extremities: study of 100 cases of embolism and thrombosis. *Surg., Gynec. & Obst.*, 63: 231 (Aug.) 1926.
2. Linton, R. R. Acute peripheral arterial occlusion and its treatment. *New England J. Med.*, 216: 871 (May 20) 1937.
3. Pearse, Herman E., Jr. Embolectomy for arterial embolism of the extremities. *Ann. Surg.*, 98: 17 (July) 1933.
4. Key, E. Embolectomy of the extremities. *Brit. J. Surg.*, 24: 350 (Oct.) 1936. Denk (quoted by Key).
5. de Takats, G. Use of papaverine in acute arterial occlusion. *J. A. M. A.*, 106: 1003 (March 21) 1936. Obliterative vascular disease. *J. A. M. A.*, 103: 1920 (Dec. 20) 1934.
6. Herrmann, L. G., and Reid, M. R. Pavaex (passive vascular exercise). Treatment of obliterative arterial disease of extremities. *J. Med.*, 14: 524 (Dec.) 1933. Conservative treatment of arteriosclerotic peripheral vascular diseases; passive vascular exercises (pavaex therapy). *Ann. Surg.*, 100: 750 (Oct.) 1934.
7. Landis, E. M., and Gibbon, J. H., Jr. Effects of alternating suction and pressure on the blood flow to the lower extremities. *J. Clin. Investigation*, 12: 925 (Sept.) 1933.
8. Lund, C. C. The treatment of the greater arteries. *Ann. Surg.*, 106: 880 (Nov.) 1937.
9. Leriche, R., Froment, R., and Vachon, A. Artériectomie pour embolie de l'artère fémorale superficiale. Rétrocession de tous les troubles. *Lyon med.*, 154: 416 (Oct. 21) 1934.

SURGICAL TREATMENT OF VARICOSE VEINS AND ULCERS BY SEGMENTAL SCLEROSIS*

WITH A DISCUSSION OF THE EFFECT ON PERIPHERAL ARTERIAL DISEASE AND THE GENERAL CIRCULATION

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IN a discussion of surgery of the extremities, the surgical therapy of varicose veins deserves consideration, not only because of the large number of affected people and the resultant disability, but also because of the newer concepts of treatment. Entrance of women into industry and athletics, wider adaptation of the causal relationship factor in compensation cases, and the recognized failure of injection therapy to effect a cure, have refocused attention on the varicose vein problem. A combination of the ligation and injection methods previously developed for the treatment of varicose veins, with the physiologically correct location of the ligation point at the saphenous-femoral valve and the even distribution of larger amounts of more effective sclerosing solutions, has improved the chances for a cure.

Without needlessly repeating the recent historical reviews of the varicose vein problem, we may mention that in the past the work of Valjean, Paré, Howe, Schede and Trendelenberg was particularly important, while C. H. Mayo and Babcock, with their vein stripping procedure, Homans, De Takats, and Faxon, have more recently contributed to the surgical progress. Injections date back to Pravoz, who first invented the syringe in 1851 (and used perchloride of iron), but it was the more recent work of Sicard and Linser, Zirn, Troisier with McPheeters and De Takats, as well as Higgins, Cattell and Rodgers that popularized the chemical obliterative treatment.

Varicose veins may be of congenital or acquired origin. The *congenital factor* is well illustrated by one patient we have seen, now under treatment, whose father died of the complications of an ulcer, and whose 12 year old son already has many dilated veins. The congenital absence of part or all of the valves in the superficial venous system is occasionally observed. One of our patients (T. F., age 11), with a "blow-out" at each communicating branch outlet, presents an instance of the absence of valves in communicating veins, proved at operation and on pathologic section.

Pressure congestion is a factor in the *acquired* type of varicose veins, of which pregnancy is an illustration. Probably as long as women have babies they will have varicose veins. The pressure on the iliac vessels during the last few months of pregnancy and in labor is the precipitating factor, but the number of women who bear children and still develop no veins testifies to the precept that in each instance there is an underlying valve or vein wall weakness. In addition to pregnancy, post-partum or postoperative phlebitis is a precipitating factor. Long hours of standing in such occupations as those of policemen, clerks, auctioneers, elevator operators, etc., as well as the use of machines with foot or thigh pedals, may produce varicose veins, but there is probably an underlying weakness of the vessels. The muscular action of walking tends to empty the veins and therefore occupations in which persons walk considerably do not frequently produce vari-

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cosities. Between 2 and 3 per cent of all patients admitted to general hospitals have pathologic veins, and of this group approxi-

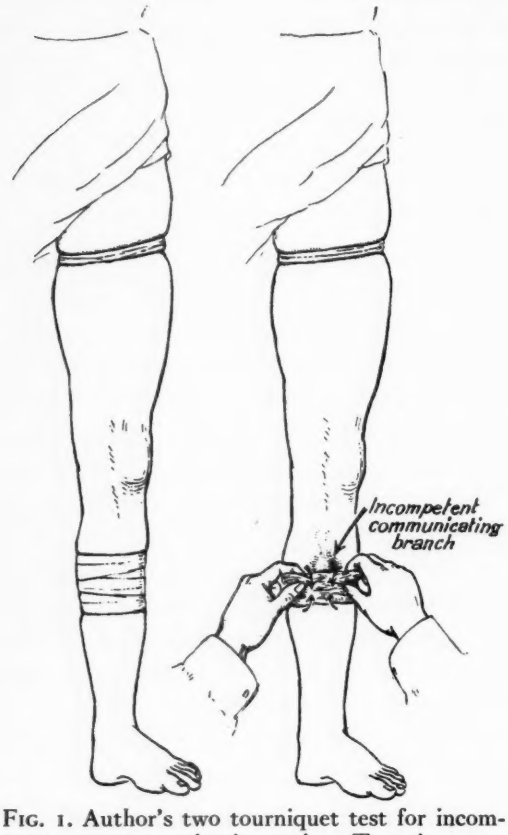

Fig. 1. Author's two tourniquet test for incompetent communicating veins. Tourniquet at upper thigh and a wide cuff below. This is rolled to its center until area of "blow-out" is demonstrated.

mately 65 per cent are complications of pregnancy. While many clinics present a marked difference in ages of the male and female groups, attributable to the pregnancy factor, our clinic draws from a poor district where patients neglect themselves and our age difference is negligible (male—41 years; female—40 years). The average period during which the patient had suffered from varicose veins before applying for treatment in our service was twelve and one-third years.

A study of the anatomic-pathologic process is of importance in understanding the condition. In the leg we have a deep femoral and a superficial, or auxiliary venous system, consisting mainly of the saphenous tree with communicating branches to the deep veins. The deep veins are well supported by large, mobile muscles and seldom develop varicosities or incompetent valves. The superficial system is without perivenal support, has smaller branches and is subject to trauma. The valvular system normally maintains a distal-proximal flow through the superficial system, collecting the blood in the great saphenous vein and emptying it into the femoral at the fossa ovale. Failure of the valvular control, especially of the saphenofemoral valve, causes a reverse flow of the blood in the superficial tree, with stretching and loss of tone of the vein wall. The femoral vein blood flows through the incompetent saphenofemoral valve and produces a stagnated, congested, superficial tree: the blood drained from the extremity by the femoral, returns to the extremities through the failing valve before it has been aerated. A vicious cycle then develops; deoxygenated blood continually bathes the lower extremity and a condition conducive to swelling, induration, dermatitis and ulcer formation develops. At times the valves of the communicating branches do not function and there is a back flow from the deep system at the communicating points, with a so-called "blow-out."

The therapeutic problem is to eliminate the permanently incompetent superficial system and force the venous drainage of the limb through the deep, well supported femoral venous system. Palliatively, this may be accomplished by elevation and bed rest, the use of a rubber stocking, or supporting bandages. With the advent of modern injection therapy of safer sclerosing solutions, it was thought that the therapeutic problem was settled. Quinine and urea solution (Genevrier), sodium salicylate (Sicard, 1918), bichloride of mercury (Hempel), the various concentrates of sugar, sodium morrhuate (Higgens and Kittel) and more recently, sodium ricinoleate (Froelich and Henrickson) and other fatty acid salt solutions, accomplished surprising results. These effects were short lived, however, and while some varicose

veins, without a positive Trendelenberg test, respond well to simple injections, it is now recognized that when the saphenous-femoral valve is incompetent, permanent results from injections alone cannot be expected. The back pressure of the reverse flow will cause recanalization, and recurrence. Forty to 60 per cent of patients after injections return with the same symptoms and open veins can be demonstrated, by needling, in 100 per cent (in twenty-nine months, according to Howard). Injection failure led to efforts to revive and simplify the operative procedures. Hippocrates had ligated the saphenous vein. Trendelenburg, with his operation of a simple ligation considerably below the saphenous-femoral opening, corrected 50 per cent. Schede's circumcision at the junction of the middle and upper third of the thigh followed and these procedures, like others, failed in a large percentage because the underlying pathology of valve incompetence directly at the saphenous-femoral junction was not recognized and treated. De Takats, Ochsner and Mahorner, Johnson, Lowenburg, Edwards, McPheeters, Howard, Cattell and Sedwitz, are a few of the many workers who reported outstanding results with the combination of ligation and retrograde injection. Many logical advances have been reported and we feel we may add to these records.

At present the saphenous vein and its branches are divided directly at the fossa ovale, a section of vein resected and the vein retrogradely injected by a sclerosing solution, with localization of the solution at multiple points. Only two absolute contraindications are considered: closure of the deep veins by previous thrombosis and the presence of an acute phlebitis.

Preoperative Preparation. A careful history is recorded and a complete physical examination made, including pelvic and rectal investigation, in an attempt to find the underlying cause of the dilated veins. The arterial supply to the part is determined by inspection, palpation and oscillometric readings. While we no longer consider defective arterial supply a contraindicating factor to the procedure, the condition of the arteries guides the amount of sclerosing solution.

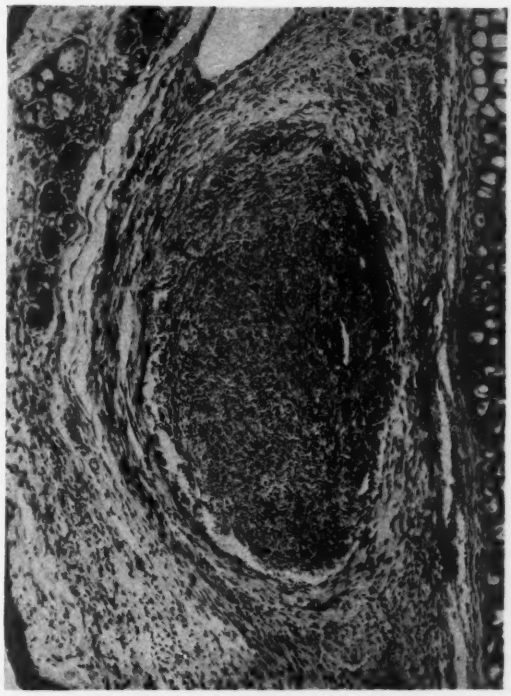

Fig. 2. Section of vein through injection point, two weeks after sclerosing injection. The wall and vein contents have been replaced by fibrosis.

Certain venous tests are performed:

1. The patency of the deep veins is assured by a simple modification of the original *Perthes test*, which is carried out as follows: The leg is elevated and a tourniquet is fastened around the upper thigh with sufficient pressure to close off only the superficial veins. The patient then walks for five minutes. There will be pain at once and marked swelling of the leg and ankle if the deep veins are closed, since the superficial venous return has also been shut off.

2. The competency of the saphenous-femoral valve is then determined by the *Trendelenberg test*. The tourniquet is placed near the fossa ovale on the elevated leg and the patient stands up. When the tourniquet is removed, rapid filling from above down, indicates an incompetent saphenofemoral valve (Trendelenberg, positive).

3. To determine if ligation at a "blow-out" point is indicated, a new *two tourniquet test* is used, as follows (Fig. 1): After emptying the superficial venous tree, a tourniquet is applied near the fossa ovale to control saphenous-femoral back flow, and a second, wide tourniquet cuff is placed on the lower leg. With the patient standing, this wide tourniquet is rolled toward its center until the point of the leak from the femoral through the communicating branches is ascertained. This "blow-out" area will be the point of the saphenous vein also requiring ligation. The location is measured from the patella. Experience shows that this occurs most frequently one hand's breadth below the patella.

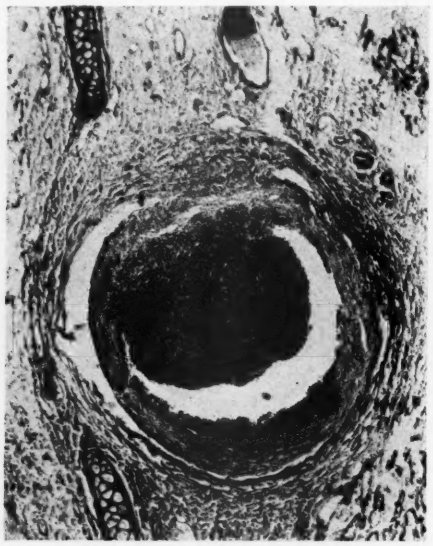

Fig. 3. Same vein 1½ inches from injection point. Notice separation of fibrotic area from wall with incomplete lumen closure and capillary spaces conducive to recanalization.

Surgical Technique. The patient is prepared simply by a soapsuds enema, a ½ per cent lysol douche in the female, and careful green soap cleansing. Iodine and alcohol are used for skin sterilization.

The fossa ovale is marked by the one-by-one rule: 1 inch below the spine of the pubis and 1 inch lateral. Other methods of determining this fossa ovale, as by the percussion reflex test (McPheeters), marking by vision when standing up, and palpation of the femoral artery and taking a point just medial to it (applicable only in thin individuals), have been found unnecessary, as even in an obese patient, the spine of the pubis can be readily felt and this simple rule invariably is sufficient.

Eighty to 100 c.c. of 1 per cent novocaine are injected radially, like the spokes of a wheel, from *one* single puncture at the fossa ovale. Possible injection of large vessels is prevented by keeping the needle constantly moving, guiding it with the other finger on the skin and occasionally drawing back on the syringe. Only local anesthesia is applicable because we desire to have the patient walk immediately after the operation.

The incision is made 1 inch below and parallel to the inguinal ligament, with the medial end of the incision at the fossa ovale, and is carried down through the superficial fascia. The saphenous vein is located by blunt dissection, its diameter measured in centimeters and a ligature guide passed around it. It is then dissected free to the femoral junction and the three most constant branches, the superficial external circumflex iliac, the superficial external pudendal and the superficial inferior epigastric, and any other anomalous branches divided and ligated with catgut. The superficial femoral cutaneous veins are not ligated. The saphenous vein is then divided at the femoral junction, the proximal end secured by a transfixion suture of catgut, and the distal end resected after dissection for a distance of 2 to 5 cm. The distal end is then opened and a ureteral type of catheter introduced for a distance of 40 to 60 cm. The introduction of the catheter is technically simple, as it slips by the valves with only a slight pressure, or twist. The injecting solution is then introduced as the catheter is withdrawn, 5 c.c. at a time, thus providing an even diffusion of sclerosing solution throughout the venous tree. The importance of introducing the sclerosing solution uniformly at different levels cannot be overemphasized. The sclerosis varies indirectly with the distance from the point of injection, and by making the points of injection close together, the

degree of sclerosis can be kept uniform throughout the vein.

To emphasize this point, photomicrographs are presented showing how localized is the effect produced by a sclerosing agent. Figure 2 shows the sclerosis *at the point* of injection of an animal's vein, with marked intimal destruction and replacement of the canal and blood by a fibroblastic proliferation. Figure 3 shows the same vein at a point 1½ inches from the injection point, with very little fibrosis and some capillary spaces, which are conducive to recanalization. Figure 4 shows the same vein 3 inches from the injection point, with no fibrosis and no intimal changes. This demonstrates how rapidly the sclerosis fades out as we move away from the injection site. This is obviated by the equal distribution of the points of maximal injection intensity throughout the vein length by the catheter. Fibrosis is more nearly complete and obliteration pathologically effective.

Fig. 4. Same vein 3 inches from injection point without fibrosis or intimal change, demonstrating how localized is the sclerotic effect.

Figure 5 shows the catheter in the saphenous vein. The solution is injected as the catheter is withdrawn. The patient then walks around the operating room for several minutes, after which an ace bandage is applied from the toes to the knee, including the heel. Any markedly discolored areas, indicating collection of sclerosing solution in dilated veins, are supported by pressure pad dressings. Walking is encouraged thereafter.

Fig. 5. Catheter inserted in saphenous vein retrogradely. The sclerosing solution is to be injected as the catheter is withdrawn.

Amount of Solution. It was apparent when we started our study that large amounts of sclerosing solution would be necessary if we desired a complete saphenous vein sclerosis. Such solutions as sodium morrhuate, with toxicity at 5 c.c. doses, were thus eliminated. After considerable experience we determined that sodium ricinoleate (3½ per cent) could be

utilized in the large amounts we desired. We obviated the local reaction which would follow such an injection through

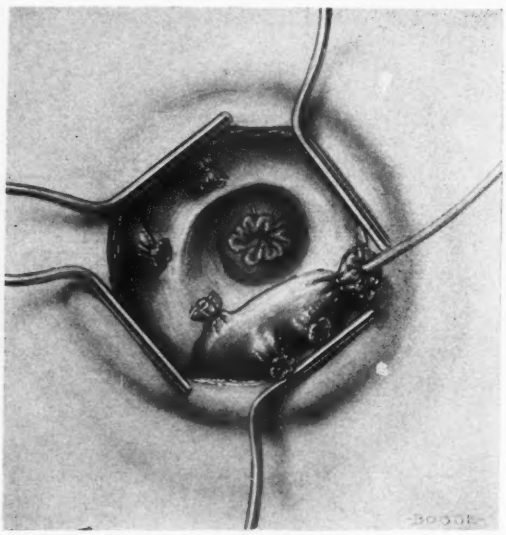

Fig. 6. Incision at fossa ovale. Saphenous vein divided at the femoral junction. Branches (superficial inferior epigastric, superficial external pudendal and superficial circumflex iliac) ligated. Catheter tied into distal end, preparatory to injection. Automatic spring retractors adequately expose the field without the obstruction of hand retractors in the small incision.

equal distribution of the injection points by the catheter method.

Due to the variation in the size and branches of the saphenous vein, the necessary amount of sclerosing solution may vary. A large vein necessarily requires more solution than a smaller one, due to greater dilution by the blood and to greater intimal wall surface. We have developed a formula which gives us a fairly accurate criterion of the amount needed for each injection. The measured width, in centimeters, of the saphenous vein at the fossa ovale and the length, in centimeters, from the fossa ovale to the internal malleolus, divided by three, calculates grossly the amount of 3½ per cent sodium ricinoleate necessary:

$$\frac{\text{Diameter saphenous} \times \text{length saphenous}}{3} = X \text{ (amount of } 3\tfrac{1}{2} \text{ per cent sodium ricinoleate (in c.c.))}$$

We have used as much as 60 c.c. of the 3½ per cent solution, although the average amount is 40 c.c. This figure is a rough one, applicable only to 3½ per cent ricinoleate and is used merely as a guide. Additional factors such as the condition of the arteries, the presence of ulcers, the general condition of the patient, etc., are important and must be considered when using this formula. Other preparations need further trial.

The injection completed, the distal end of the vein is transfixed and ligated with 0 catgut and the wound is closed, without drainage, with silkworm gut or interrupted fine No. 35 or 36 alloy steel wire. The wire is valuable if there is any wound reaction, as there is no tissue reaction to the steel, and it can be left indefinitely, even if there is drainage. The location of the wound near the scrotum or vagina makes it susceptible to infection and this is counteracted during the operation by placing the incision lateral to the fossa ovale and retracting the wound medially, and also by a careful sealing of the area after the operation. A compound tincture of benzoin dressing is applied and sealed with liquid adhesive and adhesive tape, amply painted with white shellac to make it water tight.

When indicated by the *two tourniquet test*, a second incision is made over the point of leak from the deep system into the superficial system and the vein divided and ligated with catgut at that point. Approximately, one-half of our patients require this second incision.

Formerly, in agreement with most clinics, we considered a defective arterial supply an absolute contraindication to vein therapy. After considering the physiology of osmotic pressure and capillary pressure, it seemed, theoretically, that if the venous pressure became higher with varicose vein stasis, there would be increased venous capillary pressure. Consequently, there would be increased tissue pressure against which the arterial capillaries must work. With decrease in the venous pressure and lessened edema, it seemed apparent that arterial flow should improve. On this basis, this

procedure was tried on a patient (J. S., age 55) with advanced arterial occlusion, who had claudication after one-half block. His moderately enlarged veins were eliminated by ligation at the saphenous-femoral valve and by retrograde sclerosis. The result was quite startling: the patient was able to walk five blocks. In a second patient (K. S., age 64), in whom amputation was being considered for a marked arterial sclerosis with a trophic ulcer on the dorsum of the foot, obliteration of the associated veins was followed by prompt and permanent (one year) healing of the ulcer and relief of the pain for which the patient was receiving morphine. The same venous therapy in an individual (H. S., age 34), with severe thrombo-angiitis obliterans and a chronic ulcer, closed the ulcer and gave the patient his first relief from pain—pain which had been severe enough for him to attempt suicide. Four other patients have been clinically improved and, while laboratory proof of the improved vascular supply is difficult to present, the clinical evidence is very encouraging.

In one instance of tricuspid insufficiency, with a pulsating saphenous vein, the ligation and elimination of the vein have resulted in diminution of the valvular bruit and relief of cardiac decompensation. Further studies are being made, but clinically it seems that the removal of chronic, stagnant, venous pools, against which the heart must pump, improves the general circulation. This blood load, like the pulmonary edema of heart failure, or the peripheral edema of chronic nephritis, raises the peripheral resistance and increases the cardiac effort necessary to maintain adequate circulation.

While detailed statistical reports are not intended in this discussion, we have operated on approximately 100 individuals since adopting this technique twenty months ago. Two-thirds of our patients have had ulcers and in only two cases the ulcer has not closed. Both of these patients had heavy, brawny legs, with deeply set saphenous veins, and a subsequent modified Schede operation has demonstrated an incompetent venous shunt from the saphenous to the femoral vein, just above the ulcer. One out of every three of our patients had the operation performed bilaterally. There have been no deaths in the series and no serious complications. There have been two instances of general reaction to the drug, manifested by urticaria, low grade fever and general malaise, but the symptoms were mild and subsided in a few days. The majority have a febrile reaction for two to four days and evidence of a chemical phlebitis. In two patients there was a leak through the vein wall in the lower thigh with a small area of necrosis, but these areas healed in the course of four weeks.

The question of deep vein sclerosis is always considered when chemical obliteration of the saphenous vein is discussed. While the solution theoretically may run into the deep vein by the communicating branches, the excellent valves and perivenal support, with lack of stasis in the femoral vein, makes sclerosis unlikely. The catheter method, with its constant movement through the vein course, would tend to limit the amount of sclerosing solution which might enter the deep system.

SUMMARY

1. The anatomic-pathologic cause for varicose veins is discussed.

2. Selection and preparation of patients for saphenous vein ligation and sclerosis is detailed.

3. A new test for determining accurately the site of communicating branch incompetency is shown.

4. A technique which equally distributes the sclerosing solution throughout the vein length is presented.

5. A method to act as guide in computing the amount of sclerosing solution, when using sodium ricinoleate (3½ per cent) is included.

6. The possible advantages of obliterating varicose veins when there is defective arterial supply is suggested.

7. The effect on the general circulation is stressed.

REFERENCES

Babcock, W. W. A Textbook of Surgery. Philadelphia, 1934. Saunders.

Babcock, W. W. New operation for extirpation of varicose veins of leg. *New York J. Med.*, 86: 153–156, 1907.

Biegeleisen, H. Fatty acid solutions for injection treatment of varicose veins. Evaluation of four new solutions. *Ann. Surg.*, 105: 610–615, 1937.

Cattell, R. B. Complications following injection treatment of varicose veins. *S. Clin. North America*, 9: 1445–1452, 1929.

Cattell, R. B. Treatment of varicose ulcer. *S. Clin. North America*, 11: 291–302, 1931.

de Takats, G. Causes of failure in treatment of varicose veins. *J. A. M. A.*, 96: 1111–1114, 1931.

Edwards, E. A. Treatment of varicose veins: anatomical factors of ligation of great saphenous vein. *Surg., Gynec. & Obst.*, 59: 916–928, 1934.

Faxon, H. H. End-results in injection treatment of varicose veins. Report of 314 cases from peripheral circulation clinic of Massachusetts General Hospital. *New England J. Med.*, 208: 357–361, 1933.

Faxon, H. H. Treatment of varicosities; preliminary high injection of internal saphenous vein with injection of sclerosing solutions. *Arch. Surg.*, 29: 794–809, 1934.

Hippocrates. Works, translated by Francis Adams, New York, 1886, William Wood & Co., vol. 2, p. 305.

Homans, John. Varicose veins and ulcers. *Boston M. & S. J.*, 187: 258–266, 1922.

Homans, John. The operative treatment of varicose veins, ulcers and phlebitis. *New England J. Med.*, 200: 965–971, 1929.

Johnson, G. S. Recent advances in the treatment of varicose veins. *Surgery*, 2: 943, 1937.

Johnston, C. H. Combined ligation and injection treatment of varicosed great saphenous vein. *J. A. M. A.*, 109: 1359, 1937.

Linser, P. Treatment of varices with artificially induced thrombosis. *Dermat. Ztscbr.*, 45: 22–27, 1925.

McPheeters, H. O., and Rice, C. O. Varicose veins: complications, direct and associated, following injection treatment. Review of literature. *J. A. M. A.*, 91: 1090–1094, 1928.

McPheeters, H. O. Varicose Veins with Specific Reference to Injection Treatment. Phila., 1931. F. A. Davis Co.

Mahorner, H. R., and Ochsner, Alton. A new test for evaluating circulation in venous system of the lower extremities affected by varicosities. *Arch. Surg.*, 33: 479–492, 1936.

Mayo, C. H. Treatment of varicose veins. *Surg., Gynec. & Obst.*, 2: 385, 1906.

Ochsner, A., and Mahorner, H. R. Comparative value of intravenous sclerosing substances. *Arch. Surg.*, 29: 397–416, 1934.

Pratt, Gerald H. Segmental saphenous vein sclerosis for varicose veins, ulcers and diminished arterial supply. In press.

Pratt, Gerald H. Amputations in obliterative vascular disease. *Am. J. Surg.*, 43: 573, 1939.

Rogers, L. Intravenous sclerosing solutions. *Brit. M. J.*, 2: 120, 1930.

Sicard, J. A., Parat, J., and Forestier, J. Treatment of varices by the intravenous injection of sodium salicylates. *Gaz. des bôp. de Paris*, 95: 1573, 1922.

Trendelenberg, F. Ueber die Unterbindung der Vena Saphena magna bei Unterschenkelvaricen. *Beitr. z. klin. Cbir.*, 7: 195–210, 1891.

Zirn, Camillo. *Münchcn. med. Wcbnscbr.*, 66: 382–383, 1919.

GAS GANGRENE

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THE treatment of gas bacillus infection of the extremities has become increasingly more complex since Roentgen therapy and sulfanilamide have been reported to be of value. The response of the profession of these two newer forms of therapy may be overly enthusiastic. Over enthusiasm is not infrequent when a new product or form of treatment has been introduced. We are always searching for a panacea and are too ready to place ultimate faith in it, forgetting or discarding the older methods that have withstood the clinical test of past years. As time passes the pendulum returns. We begin to find our panacea either worthless, of definitely limited value, or to be used in conjunction with our accepted methods.

HABITAT AND BACTERIOLOGY

Gas gangrene is produced by anaerobic bacilli and occasionally by aerobes. Twenty-five of the former and ten to fifteen of the latter have been isolated. The most common anaerobes are: Cl. welchii, Cl. oedematis maligni, Cl. novyi, Cl. sordelli, and Cl. histolyticus. Of the aerobes B. coli and the streptococci are the most common.

The anaerobes are widely distributed. They are found as natural inhabitants of the soil, of the intestines of human beings and of most herbivorous animals. They have been also isolated from samples of milk, spring water, shellfish, cheese, flour, wheat, barley, rice, oatmeal, gun wads, wool, air, canned sausages, potatoes, etc. These organisms have even been cultured from the mouths of newborn infants, normal salivary glands, from the pancreas, normal urine, and from the vagina. Considering the frequency with which these organisms are encountered in wounds occurring in civil surgery it is remarkable that the incidence of gas infection is not greater than reported. The cause of this infrequency is not known. It may be due to the fact that gas bacilli per se do not produce gas gangrene.

Experimentally, gas gangrene can be produced in the pigeon with only a washed culture of B. welchii. In other experimental studies on animals the investigators have found difficulty in producing the infection unless the intramuscular injection of B. Welchii is accompanied by calcium or some other foreign material. The exact nature of this action is not known. Vincent and Stodel[1] showed that in guinea pigs B. perfringes and vibrion septique injected separately produced no ill effects. When the two were injected in combination with B. sporogenes, gas gangrene was produced.

The pathologic studies of McNee and Dunn[2] were particularly enlightening in relation to the spread of gas gangrene into living and healthy muscle with intact blood supply. These authors emphasize the fact that gas gangrene starts at the site of the injured muscle and that extension of the gangrene is longitudinal within the muscle fibers. The fascial tissues tend to act as barriers to this spread. Anaerobic organisms were found distant from the active area of gangrene; it was therefore concluded that the toxin liberated by the organisms in the wounded muscle caused death of the adjacent muscle fibers. These devitalized muscle fibers were then invaded by the anaerobes, producing gas gangrene. The spread of gas gangrene in muscles whose blood supply had been impaired or occluded differed in that massive gangrene usually ensued.

Weinberg[3] classifies the gas bacilli into two groups: (1) saccharolytic and (2) proteolytic. The latter appear to thrive only after one of the former has destroyed the muscle tissue, thus preparing it for invasion. The proteolytic bacilli are supposedly responsible for the characteristic odor of gas gangrene.

DIAGNOSIS

Gas gangrene should be anticipated in all grossly contaminated wounds in which there is marked devitalization of muscle tissue. The first symptoms are excessive swelling and evidence of circulatory impairment of the part, pain out of proportion to the injury received, and an elevation of the temperature and pulse rate. The pulse rate is usually more rapid than one would expect with the degree of elevation of the temperature.

The diagnosis of advanced gas gangrene presents little difficulty. There is mottling of the skin due to ischemia, a peculiar brawny discoloration probably due to hemolysis, and the typical odor of decayed meat characteristic of B. welchii infection. After gas has formed in the tissues to such an extent that it is clinically evident, the infection is far advanced. The outcome is largely dependent upon the time of diagnosis.

X-ray of the soft tissues involved is most helpful in early diagnosis. Given a case which within a few hours after injury there are symptoms of severe pain, excessive swelling, evidence of circulatory impairment, and a rapid rise in temperature and pulse rate, until a definite diagnosis is made, *x*-rays of the traumatized portion should be taken at six hour intervals. Rhinehart[4] has shown that radiologically a diagnosis can be made in as short a time as two and one-half hours as compared with twelve hours clinically; the longest radiologic time is seventy-two hours as compared with seventy-five hours clinically; average is 18.8 hours against 50.5 hours. The mortality in the two series reported by him was 18.2 per cent in the cases diagnosed radiologically and 52.5 per cent in the cases diagnosed clinically.

Because of the great prevalence of gas bacilli in wounds, bacteriologic diagnosis alone is useless. We must combine clinical, roentgenologic and bacteriologic findings before a definite diagnosis of gas gangrene can be made. In the past, many cases have been diagnosed clinically without bacteriologic confirmation. This we believe is due to the fact that in a large number of hospitals the only culture made was that for the B. welchii. This isolated search for B. welchii should not complete the bacteriologic study. Theoretically every suspected wound should be cultured for each of the twenty-five anaerobes which have been shown to produce gas gangrene; however, for practical purposes the culture for the five most common anaerobes—Cl. welchii, Cl. oedematis maligni, Cl. novyi, Cl. sordelli and Cl. histolyticus—will usually suffice. The roentgenologic diagnosis per se is not final, as atmospheric air in the tissues may be found after closure of certain wounds, also following hypodermoclysis and hypodermic injections when all the air was not removed from the tubing or syringes prior to the administration of medication. Because of these possible errors in making diagnoses by the aid of bacteriologic and Roentgen examinations, it is difficult to evaluate the results obtained in those cases diagnosed solely by these methods.

SURGICAL CONSIDERATIONS

The treatment of gas gangrene begins with surgical prophylaxis of the wound, prior to the onset of actual infection. This treatment consists in removing all factors essential to the growth of the anaerobic organisms.

In the past we may have relied too greatly on the use of antiseptics. As emphasized so forcibly by Mont Reid[5] in a recent paper on wound healing, antiseptics are to be used with considerable care. Wound healing should not be impaired by the use of antiseptics which are apt to irritate.

Nature accomplishes healing of a wound. The surgeon should aid, not hinder this process. In many clinics the treatment of wounds consists only of cleansing with neutral soap and water, followed by irrigation of a large amount of saline. Painting the wound with brilliantly colored tinctures has been discarded.

The resection of all devitalized tissue, the careful search and removal of foreign bodies, and the drainage of pockets and dead spaces are of paramount importance. This technique has lessened considerably the time of wound healing and decreased the period of disability. Bacteria, especially the anaerobes, find little encouragement in growth in viable tissue.

Bohler[6] considers the above procedure far more important than serologic prophylaxis. He emphasizes that rents in fascia should not be sutured. nor should lacerated muscles be sutured unless there is complete transverse division. He further advocates that the wound should be left open and thoroughly drained with rubber tubing. Bohlman, in Evacuation Hospital No. 8, A.E.F., found that only 3 per cent of the debrided wounds were complicated by gas gangrene although 29 per cent of these had clinical evidence of gas infection at the time of operation, as shown by positive culture.

Since Tanner's report in 1923[7] there have been many cases reported of gas infection complicating surgically clean amputations. These reports have been summarized by Eliason, Erb and Gilbert,[8] who found that the mortality rate was exceedingly high, 59 per cent for their entire group. In patients suffering from diabetes the mortality following amputation was 75 per cent. These complications may arise from contamination without or from infection within; that is, severing lymph channels which contain the anaerobic organisms.

In respect to the first, Wright[9] found that the incidence of gas infection in leg amputations increased if spinal anesthesia was employed for amputation. This fact he attributes to contamination of the wound by evacuation of flatus and feces on the operating table and afterward in bed during first hours, secondary to the relaxation of the anal sphincters. To avoid this contamination he advised a dry perineal cotton pad covered by another cotton pad saturated with bichloride of mercury solution used during operation. The stump dressing should be covered with waterproof material to prevent contamination from postoperative fecal incontinence. Following these precautionary measures there has been a decrease in the incidence of gas infection in cases of amputation of the thigh when spinal anesthesia was employed. Wright believes that the higher incidence of gas infection in the diabetic stumps might be due to the greater prevalence of B. welchii in the feces of these patients, associated with the lowered tissue resistance.

Orr[10] feels that infection from within is through the lymphatic circulation. However, no means of combating this latter complication is known. A guillotine operation with non-closure of the stump might prove of value in such cases, where a positive culture is obtained from the gangrenous area preoperatively.

Reports of cases of gas gangrene following hypodermoclysis and hypodermic injections do occur. Fortunately this complication is infrequent. The causes of these infections are difficult to ascertain. They usually occur in the debilitated patient, and the mortality is high. Harney[11] reported eighty-six cases with a mortality of 88.4 per cent.

In the treatment of active gas bacillus infection the extent of the surgery performed must depend entirely upon the individual case. If the circulation of the extremity is unimpaired and the infection is confined to a muscle or group of muscles, wide excision of the involved muscle tissue is indicated. If the circulation of the part involved is impaired or if the muscle damage is so extensive as to involve an entire extremity, amputation is necessary. If the involvement is confined to the lower leg,

Coller[12] advocates disarticulation at the knee. If the thigh is involved, a guillotine operation above the site of the involved muscles is indicated. Eliason, Erb and Gilbert[8] have shown that a more conservative procedure, such as incision and drainage, will give better results than radical amputation in those cases in which serum or serum together with *x*-ray therapy was administered:

MORTALITY PERCENTAGE

Serum plus *X*-ray		Serum		No Serum	
Amputation, Per Cent	Incision, Per Cent	Amputation, Per Cent	Incision, Per Cent	Amputation, Per Cent	Incision, Per Cent
42	7	22	13	26	37

Millar's statistics[13] also showed a 52.5 per cent mortality in radical amputation as compared with a 22.3 per cent mortality where incision and drainage were performed prior to amputation. There has been a great trend by surgeons to limit their surgery to the removal of the devitalized tissues or simple incision, not amputating unless the entire limb has been deprived of its blood supply. This method of treatment is recommended by the United States Army Medical Corps, which advocates further that the longitudinal incisions in muscles and fascia should be made half again as long one would deem apparently necessary. The results following this method of therapy are quite encouraging.

SEROLOGIC CONSIDERATIONS

The statistics evaluating the use of gas bacillus antitoxin prophylactically or therapeutically vary greatly; those of the World War show the best results. In evaluating these statistics of military cases one is mindful of the fact that the routine use of antitoxin and the routine employment of débridement were the method of treatment. However, Vincent[14] was most enthusiastic over the use of serum, stating: "During the war not a single case of gaseous gangrene came to our knowledge amongst the numerously gravely wounded who had received the serum in preventive titre. In the field hospital where the injections could be made early, the protection assured by this method was particularly striking to all the surgeons who used it." Duval and Voucher[15] reported a reduction in mortality from 16 per cent to 3.5 per cent in those cases in which antitoxin from B. welchii and the bacillus of malignant edema was administered. Van Buren also reported the successful employment of this procedure among the British and American forces during the latter part of the World War.

The results following antitoxin prophylaxis since the war have not been so encouraging. As a result many surgeons have condemned its use. The cause of this failure may be due to an insufficient concentration of the antitoxin or to the failure to include the causative organism. Although we were unable to find any experimental evidence to support the statement, it may be assumed that the employment of gas bacillus antitoxin should be similar to the administration of tetanus antitoxin. It has been shown experimentally that the antitoxin titer of the blood following a prophylactic dose of 1,500 units of tetanus antitoxin rapidly declines and is not detectable after two to three weeks. Therefore, in wounds where gas infection is anticipated gas bacillus antitoxin should be repeated with the tetanus antitoxin.

The function of antitoxin is to neutralize the toxin formed by the various gas-forming anaerobes. As stated previously, any one of the twenty-five anaerobes and ten to fifteen aerobes may produce gas infection. Therefore, if the antitoxin administered does not include the prevailing organism, naturally there would be no antitoxic effect on the toxin produced. Until recently it has been impossible to obtain truly polyvalent antitoxin. The antitoxin of Professor Vincent is perhaps

the most efficacious at this time. This antitoxin is prepared from twenty strains of species of bacteria commonly found in gas infection. This antitoxin is, unfortunately, very difficult to obtain in this country. Theoretically, a polyvalent antitoxin given in sufficient quantity to neutralize all of an unknown amount of toxin formed should relieve the patient of the systemic reactions to this toxin.

Collander, Haim and Maximov[16] advise as prophylaxis one minimal therapeutic dose of 10,000 units Welch antitoxin with 10,000 units oedematis maligni (vibrion septique), 200 units novyi (oedematiens), 200 units sordelli, and 25 units histolyticus. This prophylactic dose should be given to every patient with suspected gas gangrene and to all patients with gunshot wounds, wounds associated with devitalized tissue, compound fractures, and extensive burns. Penfold and Tolhurst[17] found that active immunity could be produced in mice by the use of B. welchii toxoid and they are now injecting humans with an alum precipitate of the B. welchii toxin. Their work is still in the experimental stage.

The value of antitoxin in the treatment of gas bacillus infection after development of symptoms is debatable. The consensus of opinion is that it should be given. Eliason, Erb and Gilbert[8] reported a 25 per cent mortality in 224 cases treated with antitoxin and a 49 per cent mortality in 125 cases treated without antitoxin. Millar's figures[13] were 39.4 per cent for ninety-nine cases treated with antitoxin and 42 per cent for 291 cases treated without antitoxin. Duval and Voucher[15] reported a reduction in mortality from 16 per cent to 3.15 per cent after the use of Weinberg and Seguin antitoxin. Vincent[14] stated that 85.9 per cent of patients who recovered from gas gangrene during the war had been treated with antitoxin. Everidge,[18] evaluating the use of gas gangrene antitoxin, states: "Personal experience leads me to believe that in many cases it alleviates the virulence of the infection and renders certain cases more amenable to surgical procedures than would otherwise have been the case." Bates[19] reported a 50 per cent mortality in sixteen cases treated without antitoxin and a mortality of 18 per cent in sixteen cases treated with antitoxin. Ghormley[20] reported that 86 per cent of thirty-three patients recovered following the use of antitoxin.

As to the dosage of antitoxin, Callander[16] advises 100,000 to 150,000 units or more of polyvalent antitoxin to be given intravenously upon the first appearance of gas bacillus infection. We are inclined to agree with this author, feeling that if antitoxin is indicated it should be administered in sufficient quantity to combat the toxemia. The surgeon may then be able to treat the infected wound with conservative surgery instead of immediate amputation.

ROENTGENOLOGIC CONSIDERATIONS

Kelly,[21] in 1933, reported eight cases of gas bacillus infection treated with *x*-ray. Six of these were limited to the extremities, all of whom recovered. The failure of the two trunk patients he attributed to the fact that they received an insufficient amount of radiation.

In 1938,[22] Kelly further reported 143 cases collected from about 100 roentgenologists. Ten patients died as a result of causes unrelated to the gas infection. Of 105 patients suffering from gas gangrene of the extremities treated with *x*-ray, there was a 4 per cent mortality in the nonamputation group as compared with a 9.1 per cent mortality in those amputated. Kelly subdivides those requiring amputation into two groups: (1) where amputation is required because of the severity of the initial trauma (mortality 6.2 per cent); and (2) those who had therapeutic amputations performed when gas gangrene was first diagnosed (mortality 11.7 per cent). These statistics are extremely favorable and warrant consideration. However, in justice to the other forms of treatment (surgery and antitoxin) we must not lose sight of the fact that most of Kelly's cases were diagnosed

clinically and roentgenologically, without bacteriologic confirmation.

Erb,[23] using pure washed strains of B. welchii on pigeons, could not find any evidence of the beneficial effects of *x*-ray treatment when used as a prophylactic or therapeutic measure. Kelly, in 1936,[24] stated that he was unable to substantiate in guinea pigs the value of *x*-ray therapy. However, in 1938 he stated:[22] "In our animal experimental work we thought we proved conclusively that the earlier treatment was started the more easily the case was controlled and the sooner it subsided; and if treatment was started late it seemed to have much less effect." There seems to be some change of opinion between Kelly's report in 1936 and 1938.

SULFANILAMIDE

Bohlman[25] reported three cases with cures of clinical gas gangrene following compound fractures of the lower extremity treated with sulfanilamide. However, all of these patients received serum prophylactically; therefore, one is unable to evaluate the effect of the antitoxin and the sulfanilamide.

Bliss and Long noted that experimentally sulfanilamide had a preventive effect in mice whose peritoneal cavity was injected with B. welchii. Their treated mice were injected with 1 c.c. of saline solution of sulfanilamide thirty minutes before being injected with B. welchii. Erb,[23] using pigeons injected with a pure strain of B. welchii, was unable to demonstrate any beneficial effects with sulfanilamide orally administered. All of the injected pigeons died.

DISCUSSION

The fact that neither *x*-ray therapy nor sulfanilamide has proved to be of value may be due to the fact that in the experiments washed cultures of only B. welchii were used; that is, they dealt with a monobacterial infection. The beneficial clinical results of these two methods of treatment may be due to their known therapeutic effect upon streptococci, which so frequently contaminate gas bacillus infections.

Gas gangrene resulting from the anaerobic gas-forming bacilli is self-limiting, as suggested first by Novak,[26] who states according to experience learned from the World War that the time of appearance of gas phlegmon after an infliction of a wound is as follows: first day, 21 per cent of cases; second day, 33 per cent of cases; third day, 15 per cent of cases; ninth to twentieth day, 1 per cent of cases. This fact is further corroborated by the findings[27] at Base Hospital No. 15, A.E.F., where the anaerobes decreased from 38 per cent to 7 per cent during the first seven days, with anaerobic death activity practically confined to the first week after the wound was received. The death rate from the anaerobic infection alone was high but with a short period of danger to life. Many patients with gas gangrene died after the first week, not as a result of the gas bacillus infection alone, but from a rapidly accumulating toxemia resulting from the contaminating streptococci and staphylococci in the process of replacing the anaerobic organisms. A streptococcus bacteremia was the most common cause for death in the patients who survived the first seven days. With the streptococcus the principal cause for death after the first seven days, the use of *x*-ray and sulfanilamide should not be questioned as important adjuncts, as is serum, to appropriate surgery in the treatment of gas gangrene.

SUMMARY

Prophylaxis in gas gangrene consists of: (1) débridement and the thorough cleansing of early wounds; (2) prophylactic administration of polyvalent antitoxin in one minimal therapeutic dose in gunshot wounds, wounds associated with devitalized tissues, compound fractures and extensive burns.

Treatment of the active infection consists of: (1) incision and drainage of all pus pockets and dead spaces, and débridement with excision of all involved tissues; (2)

amputation only if the entire limb is involved in the infection or if the blood supply of the entire limb is impaired; (3) polyvalent antitoxin administered intravenously in dosage from 100,000 to 150,000 units if practical; (4) sulfanilamide and *x*-ray therapy for their beneficial effects on the contaminating streptococci.

REFERENCES

1. Vincent, H., and Stodel, S. *Compt rend. Acad. d. sc.*, 167: 137, 1918; 168: 188, 1919.
2. McNee, J. W., and Dunn, J. S. *Brit. M. J.*, 1: 727, 1917.
3. Weinberg. *Compt. rend. Soc. de biol.*, 78: 286, 1915.
4. Rhinehart, D. A. *Radiology*, 17: 1158, 1931.
5. Reid, Mont. *Ann. Surg.*, 105: 982, 1937.
6. Böhler, L. *Zentralbl. f. Chir.*, 60: 1227, 1933.
7. Tanner. *S. Clin. North America*, 7: 1099, 1933.
8. Eliason, E. L., Erb, W. H., and Gilbert, P. D. *Surg., Gynec. & Obst.*, 64: 1005, 1937.
9. Wright. Personal communication.
10. Orr, T. B. *Am. J. Surg.*, 25: 113, 1934.
11. Harney, C. H. *Ann. Surg.*, 109: 304, 1939.
12. Coller, F. A. *Mil. Surg.*, vol. 27 (July) 1937.
13. Millar, W. M. *Surg., Gynec. & Obst.*, 54: 232, 1932.
14. Vincent, H. *Internat. Clin.*, 4: 138, 1925.
15. Duval, P., and Voucher, E. *Bull. et mém. Soc. de Paris*, 1918.
16. Callander, C. L., Haim, A., and Maximov. *Am. J. Surg.*, 42: 811, 1938.
17. Penfold, W. J., and Tolhurst, J. C. *M. J. Australia*, 1: 982, 1937; 1: 604, 1939.
18. Weintrob, Morris, Messeloff. *Am. J. M. Sc.*, 174: 801–819, 1927.
19. Bates, M. T. *Ann. Surg.*, 105: 257, 1936.
20. Ghormley, R. K. *J. Bone & Joint Surg.*, 17: 907, 1935.
21. Kelly, J. F. *Radiology*, 20: 296, 1933.
22. Kelly, J. F., Dowell, D. A., Russum, B. C., and Colien, F. E. *Radiology*, 31: 608, 1938.
23. Erb. Personal communication.
24. Kelly, J. F., and Dowell, D. A. *J. A. M. A.*, 107: 1114, 1936.
25. Bohlman, H. R. *J. A. M. A.*, 109: 254, 1937.
26. Novak, E. *Orvoskepzes*, 25: 166, 1935.
27. Surgeon General's Report, U. S. Army 12: 407, 1919.

DIABETIC GANGRENE—A CLINICAL PROBLEM

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IT is not our purpose to present an exhaustive study of diabetic gangrene, but rather to review the more practical aspects of the problems presented by the group of 559 patients whom my associate, Dr. Theodore C. Pratt, and I have seen at the New England Deaconess Hospital during the past sixteen years. For purposes of treatment the problem of diabetic gangrene is a clinical one. Practical evaluation of a given patient's circulatory background is based upon careful clinical examination; proper treatment consists in the application of the information obtained from this examination to the particular patient under discussion in the light of the surgeon's own experience and that reported by others.

The mortality following operations for diabetic gangrene in this country varies from 13 to 65 per cent.[1] Almost without exception hospitals reporting mortality in the higher brackets have with each subsequent report shown definite and marked improvement. This improvement has come not from the institution of newly discovered surgical procedures or new methods of therapy, but rather because some one or two surgeons have become interested in the problem, have reviewed their own hospital results, and have studied those of others. Increasing experience, closer coöperation with the medical service, careful surgery, and patient attention to detail have resulted in the saving of more legs, the loss of fewer lives, and a lessening of the economic burden which these patients place upon family and community.

DIAGNOSIS

About one-half of the diabetic patients seen by us have adequate circulation to their extremities and are not included in this discussion.

The diagnosis of gangrene of one or more digits in a patient with diabetes is not difficult. If in diagnosis, however, one includes a careful evaluation of the circulation to a given foot with particular reference to its ability to permit spontaneous separation or surgical removal of a gangrenous digit, the problem then becomes a more difficult one.

For practical evaluation of the circulation of the diabetic patients at the New England Deaconess Hospital we depend entirely upon a careful history and clinical examination. We depend upon neither special tests nor special instruments.

History. *Intermittent claudication* may or may not have been present. In some cases there may be a history of pain in the legs or feet after walking and relieved by rest, which was present months or years before and which gradually disappeared as the collateral supply developed. Or it may be of more recent origin and progressive to the time of examination. In many cases it is absent. *Attacks of numbness or pain,* usually of sudden onset, are frequently described and suggest one or more minor thromboses in the past. Such attacks frequently culminate in a more severe one which brings the patient to the hospital. *Rest pain* when present is of great importance. *Pain* is not a common symptom in lesions of the feet in diabetic patients except in the presence of a markedly deficient arterial supply. When it is either associated with an area of gangrene or without any open lesion it indicates a severe degree of arterial deficiency.

Examination. Both legs are bared to above the knees. The patient is flat in bed

with the heart and extremities on the same level. *Inspection:* Much information is obtained relative to the presence or absence of arterial deficiency by careful inspection of the feet. The better the circulation, the more nearly will the appearance of the feet approach that of a normal individual. Thin, parchment-like skin, with atrophy of the subcutaneous tissues, and dry brittle nails suggest the tissue starvation that is associated with inadequate arterial supply. Rapid blanching of the foot on elevation and slowly developing rubor or cyanosis on dependency is one of the most striking and constant findings in a foot with a poor arterial supply. Not infrequently one sees a foot which in the normal resting position is blanched and in which the superficial veins are collapsed. Such a foot is promptly recognized as one with extensive arterial disease and poor prognosis. It is important to note the upper limit of color change when the foot is dependent, since a major amputation, if necessary, must be well above this level.

Palpation: Temperature variations as elicited by the hand are sufficiently accurate for clinical purposes. The same levels on the two sides and different levels on the same side are carefully compared. Not infrequently one is surprised to find a definite level of temperature change in the upper third of the lower leg, with only a minor lesion on one of the toes. Such a level may or may not correspond with the level of color change and is indicative of extensive arterial disease and suggests a very guarded prognosis. Palpation of the peripheral vessels, the dorsalis pedis, anterior tibial, posterior tibial, popliteal and femoral arteries is of greatest importance. Of these the femoral and the dorsalis pedis vessels are most easily palpated and the latter is by far the most important. Failure to feel pulsation in this vessel, particularly if there is active evidence of arterial insufficiency, indicates advanced obliterative disease and warrants a cautious prognosis.

PREVENTION

No discussion of diabetic gangrene is complete without a consideration of its prevention. A large number of patients in the sixth decade and over have obliterative arterial disease, many depending entirely upon collateral supply. Such patients may well remain free from gangrene indefinitely if a break in the skin can be avoided. Poor eyesight, absence of normal sensation to pain, heat, or cold, and a lowered threshold to tissue damage all contribute to the development of some minor injury which may result in the loss of a limb or a life.

Of greatest importance in the prophylactic care of the feet are:

1. Epidermophytosis. Without question secondary infection and necrosis arising in a small fissure between the toes is one of the most common precipitating causes of gangrene. The feet must be carefully examined for evidence of this infection.

2. Burns or blisters often follow the use of hot bricks, hot water bags, electric pads, new shoes, or wrinkled socks. *Never advise any diabetic patient to apply heat to a lower extremity.*

3. Care of the nails, calluses, and corns should be entrusted to one of experience in podiatry and understanding of the diabetic state. It may be done by an intelligent member of the family, but never by the patient.

NON-OPERATIVE TREATMENT

In the earlier stages of obliterative arterial disease and for minor areas of gangrene it is the aim of non-operative treatment to (1) control infection; (2) relieve pain; and (3) stimulate the development of collateral circulation (or, as frequently happens, to readjust the circulatory needs of a foot to its arterial supply). These results we try to obtain by

1. Rest in bed with sufficient medication to control pain. It is imperative that the resting position of the involved foot be such

that the foot is not blanched (Buerger's angle of circulatory sufficiency).

2. Large warm packs of saturated boric solution, which are used to control a spreading infection.

3. Local applications, depending upon the local condition. The following medications have proved useful to us over an extended period of time: Dakin's solution; hexylresorcinal, solution S. T. 37 (1:4); azochloramide, 1:3300 in saline or 1:300 in triacetin; cod liver oil ointment; thioglycerol.

4. Careful hygiene of both feet, avoidance of pressure areas by the placing of a small pillow just above the heel, daily massage with hydrous lanolin, and careful podiatry.

5. Buerger's postural exercises[2] as modified by Allen[3] except in those cases with lymphangitis or spreading infection.

6. Intermittent venous compression as suggested by Collins and Wilensky[4] which has been used during the past six months and appears to have a definite place in the treatment of these cases.

7. General supportive measures such as iron for anemia, a well balanced diet, and high fluid intake.

OPERATIVE TREATMENT

Indications for Operation. 1. Gangrene. Gangrene in a pulseless, painful foot is an indication for amputation, unless it is superficial and limited to the tip of a digit and shows evidence of healing without pain at the end of three weeks' hospital treatment as previously outlined. Operation is also indicated for:

Gangrene of one or more toes involving the deeper structures of the foot in the absence of good pulsation in the dorsalis pedis artery, and

Gangrene of all or part of a digit associated with lymphangitis, a pulseless foot, and failure of the infection to disappear under careful treatment.

2. Pain without Gangrene. The painful, pulseless foot which is unrelieved after three weeks of hospital treatment has insufficient blood supply to be of use and should be treated by amputation.

3. Osteomyelitis of a Phalanx. Osteomyelitis of a phalanx is an indication for operation. Any unhealed ulcer of two weeks' duration overlying or on one side of an interphalangeal joint is regarded as actual or potential osteomyelitis. A positive diagnosis can be made earlier by demonstrating bare bone with a small probe than by the use of *x*-rays. Osteomyelitis involving the tip of a phalanx in relation to the nail bed may heal without operation other than the careful removal of all or part of the nail.

Selection of the Level at Which Amputation Should Be Performed. In Table 1 are listed all of the operations which have been done for diabetic gangrene at the New England Deaconess Hospital between January 1, 1923 and January 1, 1939. Almost without exception any operation on the foot of a diabetic patient with gangrene will necessitate at least the removal of a toe. Excision of an area of gangrene or incision and drainage of a food is indicated only in unusual conditions. During the past sixteen years it has been performed in this group of patients only eight times.

Decision as to the level at which amputation should be done may be easy or it may be very difficult. There are certain facts which should be taken into consideration:

1. The diabetic patient is usually as old as his age in years plus the duration of his diabetes.

2. Treatment by trial and error is extremely dangerous and usually unsuccessful.

3. Once gangrene has developed, the tendency to develop septicemia may be greater than the tendency to develop adequate collateral circulation.

4. Unless the patient's general condition is such as to permit the use of an artificial limb, there is no advantage in saving a knee joint.

5. A carefully done supracondylar amputation using a circular incision is a simple and safe operation, and in our own experi-

ence is followed by first intention healing in 93 per cent of the cases.

6. Faint pulsation in the dorsalis pedis artery is little or no better than no pulsation.

7. Successful amputation of one or more digits for gangrene in the absence of pulsation in the dorsalis pedis artery has occurred in only twenty-five* or 12.5 per cent of the last 200 cases operated upon by us, and amputation of one or more digits in the absence of pulsation in both the dorsalis pedis and popliteal arteries has been successful in only three of the 200 cases.

Amputation of a Toe. Successful amputation of one or more toes was done in 9.3 per cent of all our cases operated upon for gangrene. It is usually safe and may be successful, providing there is no lymphangitis, for: (1) osteomyelitis of a phalanx without actual gangrene; (2) localized gangrene of the tip of a digit if there is good pulsation in the popliteal artery, if the foot is warm, of good color, and with no definite level of temperature change, providing the patient is not having severe pain after two weeks of hospital treatment; and (3) in the presence of good pulsation in the dorsalis pedis artery.

Amputation through the Upper Third of the Lower Leg. This may be safely and usually successfully done in a patient under 70 years of age who is in good general physical condition providing (1) there is good pulsation in the popliteal artery; (2) the skin at the level of incision is in good condition; (3) there is no temperature or color change above the ankle; and (4) there is no evidence of infection in the lymphatics or veins above the level of the ankle.

Gritti-Stokes Amputation. Such an operation should not be done for a diabetic patient unless the surgeon has had a good deal of experience with it. It does not have sufficient advantages over a supracondylar amputation to compensate for the increased technical difficulties. It gives an excellent stump. It has the same requirements as an amputation through the lower leg except that good collateral circulation around the knee is of more advantage than pulsation of the main vessel. It is particularly useful for a heavy man who will be on his feet for long periods at a time.

Callender's[5] modification of this operation has not been used by us, but has found much favor on the West coast and should be a much safer procedure than the more complicated Gritti-Stokes amputation.

Amputation through the Thigh. Supracondylar amputation is in our experience the simplest and safest operation. It is indicated for (1) a condition permitting primary suture but requiring the shortest and safest operation; (2) conditions that will prevent the subsequent use of an artificial limb, such as failing eyesight (not due to cataracts), mental instability, etc.; (3) inability to feel any popliteal pulsation, unless the skin is warm and of good color

* This is in sharp distinction to the group of patients with good pulsation in the dorsalis pedis artery, where 136 or 68 per cent of the last 200 patients have had one or more toes removed successfully.

Table 1
OPERATIONS FOR GANGRENE
1923 through 1938

Operations	No. of Cases	Deaths	Mortality, Per Cent
Amputation of one or more toes	56	4	7.1
Amputation of toe, then major amputation	40	4	10
Incision and drainage only	8	0	0
Incision and drainage, then major amputation	3	2	66.7
Guillotine amputation	34	15	44.1
Lower leg amputation	37	2	5.4
Gritti-Stokes amputation	81	11	13.6
Thigh amputation	300	35	11.7
Totals	559	73	13.1
Toe amputations*	96	8	8.3
Major amputations*	495	69	13.9

* It has seemed wise in presenting the final statistics to include in both these groups the forty patients who had major amputations following the unsuccessful removal of one or more toes.

at least to the level of the ankle; (4) failure to palpate the femoral artery in the groin; and (5) extensive infection which makes lower amputation unsafe.

Guillotine amputation is restricted to (1) the patient with septicemia, actual or suspected, from a badly infected or gangrenous foot; (2) the very sick patient with extensive sepsis; and (3) the patient who has a gangrenous foot with extensive lymphangitis, in whose case primary suture would be unsafe.

ANESTHESIA

Spinal anesthesia, using 50 to 75 mg. of procaine hydrochloride, is our anesthetic of choice. Chloroform or avertin is too dangerous and should not be used. Ethylene-oxygen, cyclopropane-oxygen, or nitrous oxide-oxygen are preferred by some, but we believe it easier to learn to give a low spinal than a safe gas oxygen anesthesia.

TECHNICAL CONSIDERATIONS

The many details of technique in the preparation of patients for operation and of the operations themselves have been given in the past and need not be repeated here. Certain of the more fundamental principles may be repeated, however:

1. Circulation at the level of operation must be adequate to localize infection and permit repair to take place.

2. Drainage must be dependent and complete. A continuous incision is preferable to counter incisions.

3. Incisions must be so placed as to minimize interference with the blood supply and, at the same time, permit extension of the wound should further infection occur.

4. Whenever possible, amputation of a toe should be through the base of the proximal phalanx. If infection has extended into the foot, removal of the head of the affected metatarsal may be indicated and should be done through an extension of the same incision. The entire head and any sesamoid bones present should be removed.

5. Major amputations (except guillotine) must be done through good skin at a level of adequate circulation, though only very rarely above the supracondylar level.

6. We have used both fine silk and fine catgut for sutures and are unable to demonstrate any clinical advantage of the former. We feel that catgut, not heavier than No. 0 chromic, is preferable to silk in the hands of the average surgeon.

7. Guillotine amputation is usually done at or just above the fleshy part of the calf of the leg, rarely above the knee. The skin, muscle, and bone are cut in one plane. Boric or cod liver oil ointment dressing is applied and changed every three or four days. Re-amputation at a higher level, usually just above the condyles, is done after ten days or two weeks if a satisfactory response has been obtained. Guillotine amputation below the knee is the only amputation in which we feel free to use a tourniquet.

RESULTS

Six per cent of 138 patients who were treated for gangrene without operation at the New England Deaconess Hospital from 1935 to 1938 died from other causes, usually cardiovascular, during their hospital treatment. The mortality of all operations in 559 patients was 13.1 per cent, that for major amputations being 13.9 per cent. The difference between the 6 per cent mortality in the non-operative group and the mortality of those operated upon represents the mortality of delay, improper selection of operation, or technical error. We cannot urge too strenuously the careful study of the individual patient, painstaking attention to detail in the minor as well as major surgical procedures and, above all, early and prompt amputation as soon as the indications are definite.

SUMMARY

The clinical problems presented by the 559 diabetic patients operated upon for gangrene have been reviewed.

The indications for major and minor amputation are discussed.

The mortality following major amputations in 495 patients has been 13.9 per cent.

The mortality following primary supracondylar amputations in 300 cases has been 11.7 per cent.

REFERENCES

1. John, H. J. *Ann. Surg.*, 108: 1052, 1938.
2. Buerger, L. Circulatory Disturbances of the Extremities. Philadelphia, 1924. W. B. Saunders Company.
3. Allen, A. W. General management of circulatory disturbances of the extremities. *New England J. Med.*, 204: 859, 1931.
4. Collins, W. S., and Wilensky, N. D. Use of intermittent venous compression in the treatment of peripheral vascular disease. *Am. Heart J.*, 11: 705, 1936.
5. Callender, C. L. A new amputation in the lower third of the thigh. *J. A. M. A.*, 105: 1746, 1935.

Yesterday's meals are forces that shape today's fate and tomorrow's destiny. It was a slender Napoleon that won the world at Austerlitz and a fat Napoleon that lost it at Waterloo. The battle won on the playing-fields of Eton was lost at the dinner tables of Versailles.

PROBLEMS OF PAIN REFERENCE TO THE EXTREMITIES*

THEIR DIAGNOSIS AND TREATMENT

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PAIN arising in the extremities or referred to them may be caused by a large number of conditions. From a practical clinical standpoint, the recognition of the cause and the solution of the problem usually depend upon a clear understanding of a few important fundamentals concerning the pain mechanism, its origin, purpose and pathways, as well as the type of pain complained of and the type of individual suffering the pain.

First of all, the patient must be able *accurately to describe* the sensation of pain, discomfort or suffering in definite terms which remain identical upon repeated questioning. Vague and variable references will only lead the examiner astray.

Secondly, the patient must *trace, localize,* give the *direction* of, or *carefully indicate* (with one finger if possible) exactly where the pain seems to be. This part of the examination must be repeated until it is certain that patient and examiner alike are agreed upon its location and extent.

Thirdly, the character of the pain must be carefully considered in regard to intermittence, nocturnal or diurnal qualities, factors concerned with exacerbation or relief; if possible the clinician must try and establish its predominating quality so as to permit its classification into one of the three following groups:

I. Sharp, stabbing, shooting, lightning-like, cramp-like, etc.

II. Burning, scorching, tingling, etc.

III. Dull, aching, throbbing, boring, pressure-like, etc.

In group I the violent sharp, stabbing-like pain may be considered similar to that experienced when a nerve in a tooth has been touched by a dental instrument. The true *neuralgias* are immediately detected in this category and this type of pain usually indicates intrinsic involvement of the nerve or its roots.

In group II the sensation of burning is similar to that experienced when salt is introduced into an open wound or the character of tingling noted when a nerve has temporarily recovered from what is termed "going to sleep." The *causalgias* belong in this division, and although they may vary greatly as to degree, if they are carefully described there is little difference between the many kinds. This type bespeaks compression, *mild traumatic injury*, recovery from severe trauma, or *constriction by adhesions* along the nerve or its roots

Group III gives rise to a dull ache like that encountered in a bruised shin bone, the swelling after trauma, a throbbing headache, etc. This type indicates a *vascular pain* mechanism and is commonly associated with some distention or *stretch* of the arterial and capillary network of vessels, as well as stretch of the peripheral pain network. It usually is associated with some process of inflammation, hyperemia, swelling or edema.

In some instances two or three of these groups may be combined so that the additional time spent in questioning the patient and rechecking each detail of his story for accuracy will indicate the degree of complexity of the problem or perhaps save the examiner the confusion and dismay that accompanies the final discovery that the patient really was distressed with a "feeling of *pressure* rather than *pain*" or that the exaggerated and inaccurate statements

* From the Neurosurgical Service of the Temple University Hospital.

of the psychalgic patient had led him astray because they had been allowed to stand unchallenged.

visualize clearly the pain structure and its pathways. This is not difficult when we realize that the pain mechanism is the most

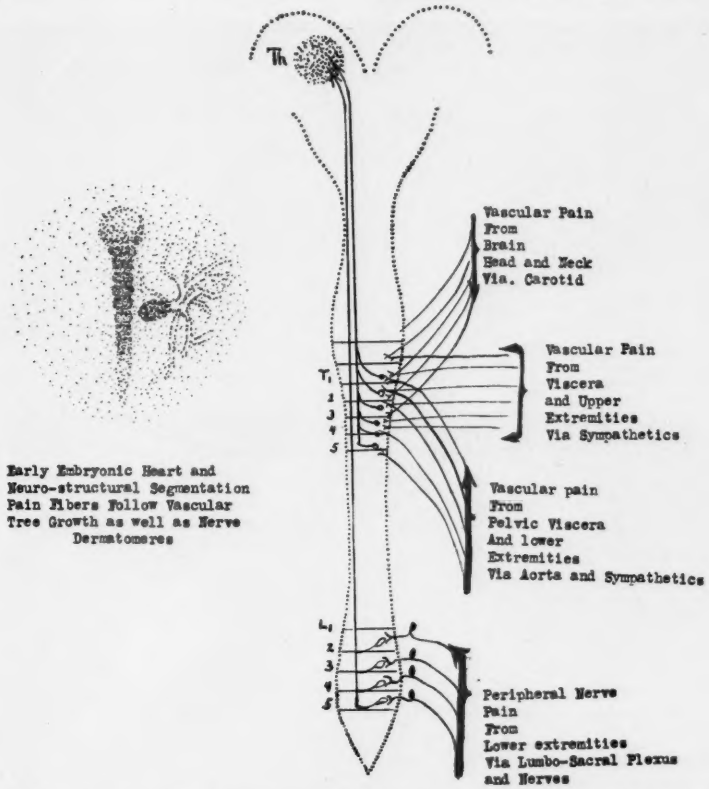

Fig. 1. Diagrammatic representation of vascular pain mechanism and its area of entry into the spinal cord. The proximity of the embryonic heart and vascular pattern to the developing segmentation of the nervous system probably accounts for the convenience of these fibers reaching the spinal cord between the first and fifth thoracic segments. This gives rise to two pain mechanisms which require individual consideration in pain problems, especially those associated with the lower extremities and the thoracic viscera.

Patients with pain demand sympathetic understanding and treatment. Nevertheless, the clinician must be constantly on guard lest he misinterpret the symptoms and, having been misled, finally fail of a diagnosis or resort to unjustified narcotics to give relief.

I consider the above approach to the problem the most important phase of the examination because it not only suggests the probable location and character of the lesion from the pain structures involved, but establishes the emotional aspects and reliability of the patient as well.

The next important consideration when dealing with a mechanism of pain is to

primitive of the sensory family. There are no differentiated end organs, merely a fine gauze-like network of fibers that is spread over the external surfaces of the body for the purpose of warning and protection, and over the capsules of certain organs as well as the arterial coats and to some extent the large venous sinuses.

In the early development of the embryo the heart and vascular pattern are first to arise along with the somites and the neural tube. (Fig. 1.) As a result, the pain fibers which are phylogenetically the most primitive, reach their destinations over two chief systems or pathways: (1) the segmented spinal peripheral nerves and certain cranial

nerves; and (2) the vascular tree. For instance, the parietal peritoneum is supplied with pain fibers from branches of the segmental spinal-peripheral system, whereas the visceral portions, including the gut tube and certain organs, receive their pain supply from the vessels, along with fibers through the large sympathetic plexuses. Pain from the former can be controlled by dealing with the segments involved; pain from the latter requires an entirely different attack upon the fibers that find entry into the spinal cord in the upper thoracic area.

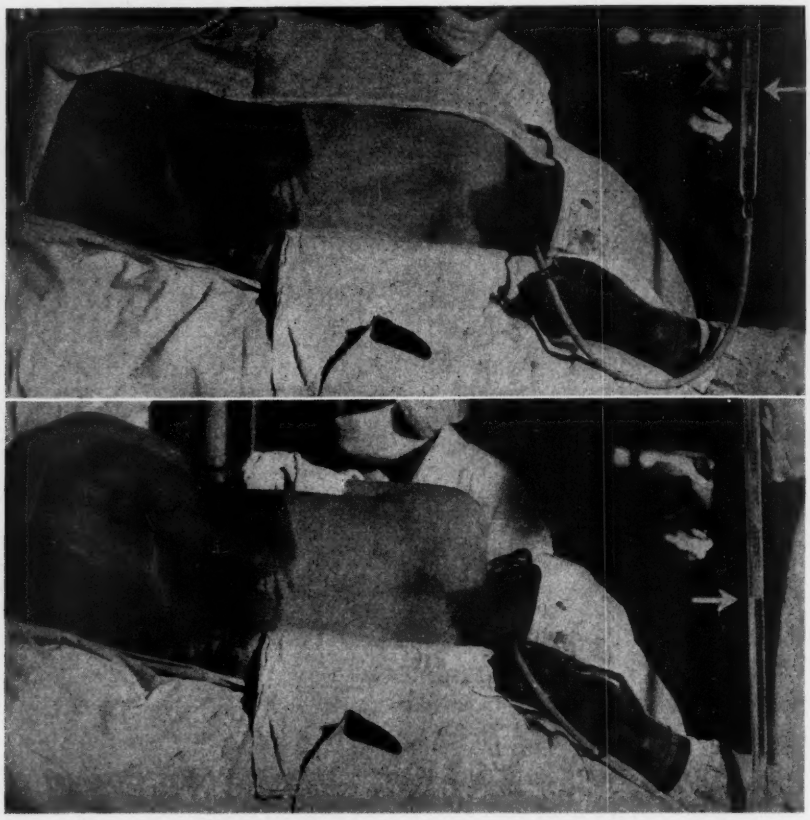

Fig. 2. The upper illustration shows the burette elevated above the level of the lumbar needle; the system is tested to determine whether or not a free flow of spinal fluid occurs out of the lumbar needle. Note the level of fluid in the burette and the pinch clamp for closing the system. The lower illustration shows the burette lowered to the desired level. The upper level of fluid in the burette is on a plane with the highest point of anesthesia required. The anesthetic is introduced through the lumbar needle as the column of fluid descends. (From Fay, in *Arch. Neurol. & Psychiat.*, 30: 1278, 1933.)

Before taking up certain frequent peripheral pain problems, one may cite here the all too frequent problem of painful so-called "amputation neuroma" of the lower extremity, the symptoms of which may persist even after complete destruction of the peripheral nerves and their roots, even when complete superficial anaesthesia exists. Here the pain persists because the vascular pathway remains open from the level of the amputation through the iliac artery and aorta to the high thoracic cord. Complete relief of pain in such cases can be obtained only by *chordotomy* (Spiller operation) of the anterolateral columns of the cord above the first thoracic segment on the opposite side. Less satisfactory results are noted when *rhizotomy* (section of the posterior roots) is applied to the first five thoracic roots on the same side as the pain. The arbitrary destruction of the second and adjacent thoracic cervical ganglia (thoracic raminectomy or ganglionectomy) in the hopes of catching most of these

vascular pain fibers as they enter the spinal roots is strongly to favor blind chance or luck rather than scientific reason, for the proportionate distribution of pain fibers varies greatly in different individuals, and although we know the majority of the vascular pain fibers enter the upper five thoracic roots, the exact root or roots carrying the fibers desired can only be determined accurately by the following clinical test especially devised for this purpose (Fay and Gotten[1]).

CHART I

Structure Stimulated (Observations by Author)	Area of Reference	Type of Pain
Brain cortex (ascending parietal convolution)	Contralateral. Hands, feet, arms, legs, trunk, etc.	Burning, tingling electrical, pins and needles
Brain cortex—elsewhere	None	None
Middle cerebral artery (at and below Sylvian fissure)	Homolateral side of head—deep in eye. Diffuse, deep hemicrania.	Severe ache, diffuse ache, pressure ache
Middle cerebral artery (Branches above Sylvian fissure)	None	Rarely any response
Anterior cerebral artery (region of corpus callosum)	Homolateral and midline forehead deep above and behind eyes.	Severe ache, pressure and throbbing ache
Posterior cerebral artery (near circle and crus)	Homolateral to parietal area. Deep in eyes.	Severe ache, pressure pain.
Internal carotid artery	Homolateral to lower half of head. Deep in eyes	Severe hemicrania. Sharp and aching
Middle meningeal artery	Homolateral to temple. Side of forehead and anterior vertex. Deep in eye.	Severe ache radiating from temple
Thalamus (pathologic involvement)	Large contralateral areas	Burning and hyperalgesia. Tingling.
Neck		
Carotid artery (Bifurcation)	Teeth, gums, upper jaw, head	Severe, aching throbbing.
Anterolateral column (cervical cord)	Opposite arm or leg	Sharp shooting burning and tingling.
Posterior spinal roots	Same side and definite dermatomere pattern	Sharp, shooting, tingling and burning.
Peripheral nerve	Distinct to peripheral nerve pattern	Tingling, pins and needles, burning.
Subclavian artery	Shoulder and arm	Intense pressure pain, ache, throb.
Iliac artery	Groin and leg	Intense pain, aching, sickening, diffuse throbbing.

Controlled Ascending Spinal Anesthesia Test. The patient is placed with the hips slightly above the level of the head. (Fig. 2.) Lumbar and cisternal needles are introduced. The cisternal needle is attached to a burette system containing sterile saline. When the stilette is removed from the lumbar needle, fluid in the spinal canal will seek the level of the fluid in the burette. If the burette is lowered, the fluid level in the spinal canal falls and air is drawn into the spinal canal as the spinal fluid drains into the cisternal area and the burette. The fluids within and without the canal will find

almost a common level if the burette is placed so that the level of the fluid can be adjusted at any point along the spine and hence along the spinal cord. (Fig. 3.)

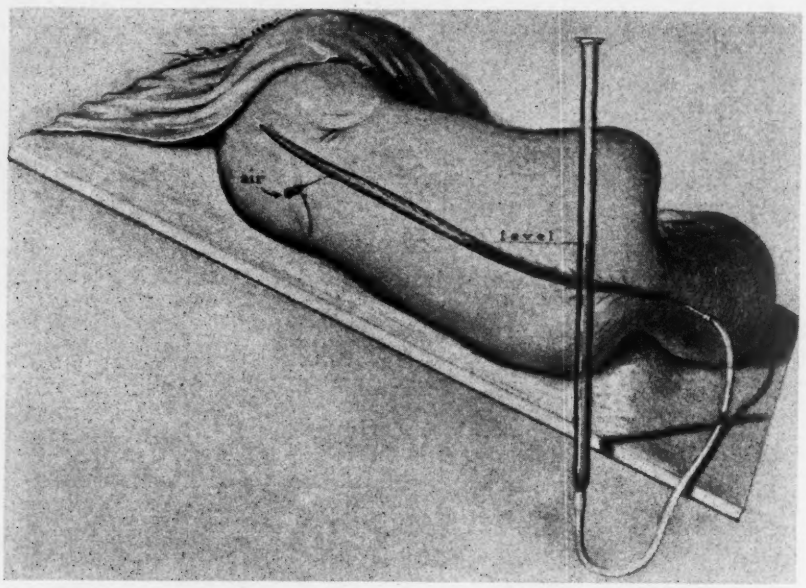

Fig. 3. Diagrammatic representation of an equilization of fluid levels within the spinal canal and the burette. (From Fay, in *Arch. Neurol. & Psychiat.*, 30: 1278, 1933.)

In order to control the exact level of anesthesia, as well as to extend it higher, as appropriate tests and observations are being made, a "light" form of spinal anesthesia (spinocaine) is allowed to run into the lumbar needle just as the column of fluid in the canal starts to fall. As air is drawn into the canal above the spinocaine, the roots and the cord are bathed in anesthetic. Thus, as more and more of the cord and its roots are anesthetized, the level where all pain response ceases can be determined and the exact roots identified by their corresponding skin segments which can be recognized subjectively and objectively.

Appropriate root levels for rhizotomy may be established by this test or the fact that pain is carried by other pathways than the peripheral nerve system. Consequently, unnecessary and futile peripheral measures for relief of pain may be avoided. The test further serves as a differential diagnostic means for distinguishing between the psychalgias and the organic group.

Peripheral nerve and root patterns of pain become extinguished with anesthesia of their respective dermatomeres. Vascular patterns are extinguished only with anesthesia of certain roots between the eighth cervical and fifth thoracic segments of the cord.

The surgical measures available for relief of pain today meet almost every requirement. Some are more serious than others. From the standpoint of the pain mechanism, they may be listed in a centripetal manner.

(*a*) *Local Measures.* Surgical relief of constrictions, adhesions, correction of neuromas, removal of painful parts and areas when indicated. (*Lo*, Fig. 4.)

(*b*) *Nerve Block.* Injection of 95 per cent alcohol into the sensory nerve trunk supplying the area involved. (I have found it possible to inject even small sensory branches by attaching one pole of the faradic battery to a fine hyponeedle. The response to a small current will indicate the exact location of the nerve.) (P.N. Fig. 4.)

(*c*) *Paravertebral Block.* This is used in an attempt to produce more lasting effects by destruction of the ganglion cells by 95 per cent alcohol. Some vascular pain fibers can be reached by this means and results are often gratifying. Inaccuracies as to the exact ganglia desired as well as technical

errors make the method unreliable and variable as to results.

(*d*) *Paravertebral Ganglionectomy or Raminectomy*. This procedure concerns avulsing or dissecting out the desired sympathetic ganglion, as well as section of the rami communicans. Although used primarily for its effect on vasomotor prob-

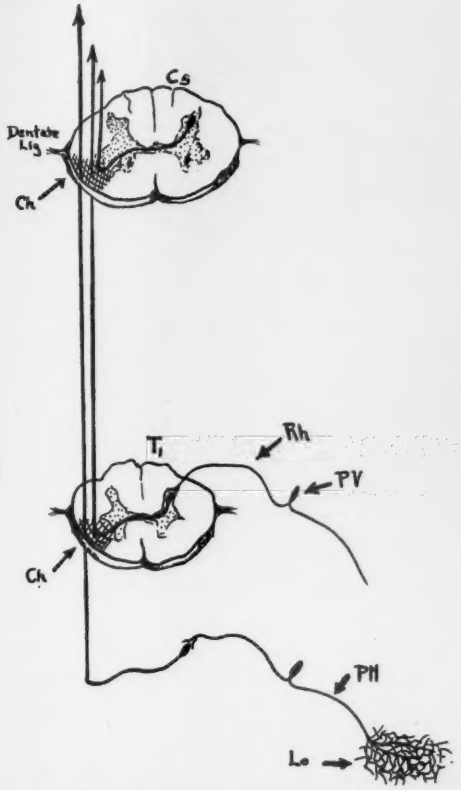

Fig. 4. Diagrammatic representation of the position of the pain fibers in the spinal cord and their relationship to the peripheral pain mechanism. The various levels for surgical control of pain are indicated.

Cb (Chordotomy), section of the anterolateral column for relief of pain; superficial fibers from the lower extremity of the opposite side. Chordotomy at C_5 required in order to include vascular pain fibers from head, trunk and extremities. Chordotomy at T_1 insures vascular and peripheral pain fibers from the lower extremity and pelvic viscera.

Rb, posterior root carrying pain sectioned or destroyed in rhizotomy. One or more roots may be destroyed depending upon extent of symptoms.

Pv, perivertebral injection with 95 per cent alcohol frequently used in an attempt to secure both vascular and peripheral pain fibers. Accuracy of the injection as well as definite ganglia selected will determine the result.

PN, peripheral nerve block by alcohol or section.

Lo, peripheral pain network controlled by means of local anesthesia.

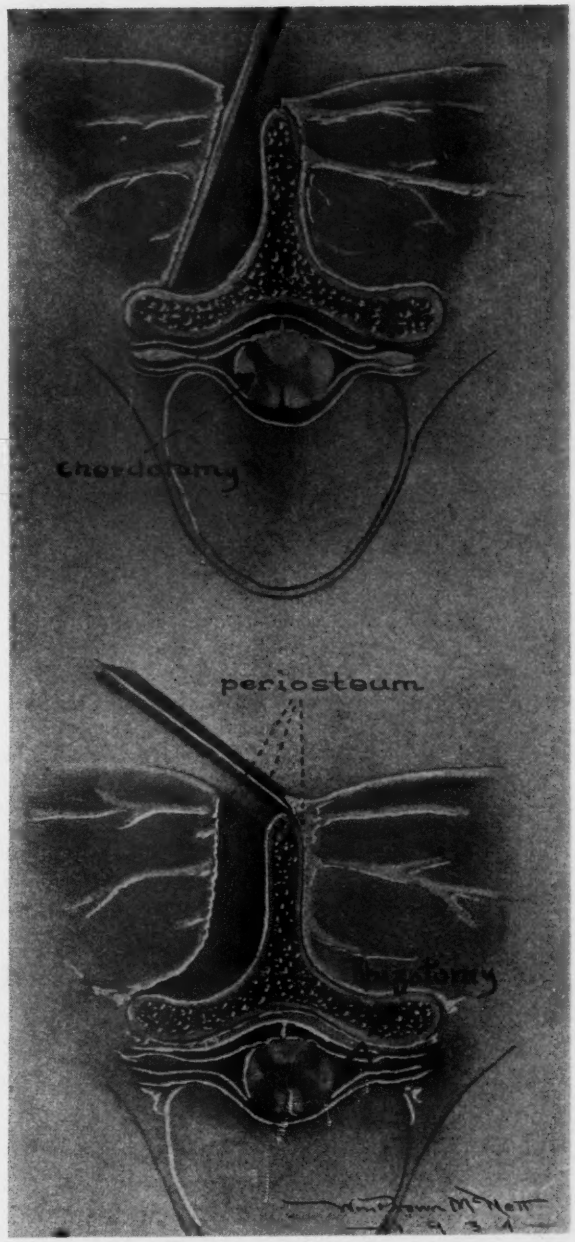

Fig. 5. Subperiosteal exposure of the lamina with preservation of the muscle bed attachments and lateral extension so as to include the base of the lamina and its articular surface. For chordotomy, visualization of the lateral surface of the cord must be obtained in order that accurate section of cord fibers may be secured. A hemilateral laminectomy is often sufficient. For rhizotomy, the dorsal roots must be exposed and laminectomy of two or more segments is required (From Fay, in *Pennsylvania M. J.*, May, 1935.)

lems, relief of pain has been noted and is to be expected where certain vascular pain pathways are involved, especially in the upper thoracic region, as shown in Figure 1. This procedure if properly performed and properly placed will relieve all pain on the opposite side. Bilateral chordotomy has been possible in some cases without other

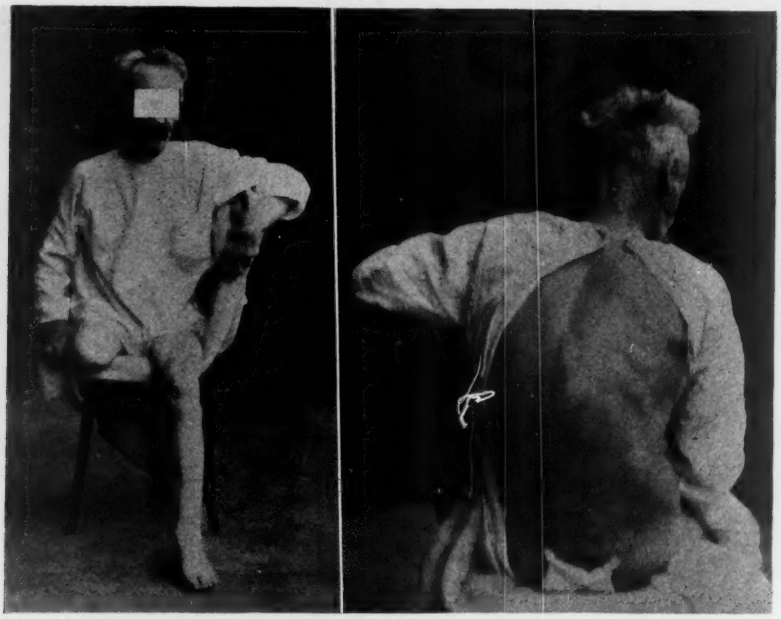

FIG. 6. Patient suffering residual pain in stump following amputation for Buerger's disease. Note attempts to control pain by injections of the sciatic, its roots, as well as the scar of rhizotomy with destruction of the sensory roots of the lumbosacral cord on the right. In spite of apparent total anesthesia, pain persisted. Ascending spinal anesthesia test revealed relief of pain only when anesthesia included the third, fourth and fifth thoracic roots on the right. Observations on this patient (1931) led to the discovery that vascular pain fibers enter high in the cord and chordotomy at T_1 was required to relieve this type of pain.

(*e*) *Rhizotomy*. This may be classed as a major operative procedure and requires laminectomy with exposure of three or more roots of the spinal cord. The desired posterior sensory roots are carefully identified, crushed and sectioned. (Fig. 4, *Rb*; Fig. 5.) The patient should be permitted to come out of the anesthetic and identify the pain and its location, when the suspected roots are carefully stimulated. Rhizotomy destroys *all* other forms of sensation as well as pain. It is therefore not desirable in problems involving the fingers, hands or feet. An anesthetic hand is quite useless.

(*f*) *Chordotomy* or section of the anterolateral columns of the spinal cord destroys only the sensation of pain. If the cut is made slightly greater in extent, perception of extremes of heat and cold is also lost. disability. The exact position of the anterolateral columns must be known for the various levels at which chordotomy is to be done. The relationship of these cord pathways to the dentate ligament must be established. (Fig. 4, *Cb;* Fig. 5.)

Figure 4 (*Cb*) indicates two levels for chordotomy; T_1 (thoracic 1) is most desirable for pain in the lower half of the body. Peripheral nerve and vascular pain fibers from the legs have all entered and crossed below this level. Chordotomy at C_5 (cervical 5) is necessary to destroy vascular pain fibers from the head, neck and thorax. It will also relieve peripheral nerve pain in the upper extremity as far up as the shoulder cap. Chordotomy at other levels may be indicated, provided the ascending spinal anesthesia test assures relief of symptoms.

The popular level of T_5 for chordotomy, in the past, failed often to relieve problems involving vascular pain of the lower extremities, because these fibers entered the cord along roots T_2, T_3, T_4 and T_5 above the level of section, and the patient, although showing objective signs of superficial anesthesia in the leg, often still complained of pain, to the dismay and confusion of the neurosurgeon. Spiegel[2] has pointed out intersegmental pathways of pain that may account for certain unrelieved cases. Chordotomy as an operative procedure is the method of choice, as it can be done quickly through a small area and with little attendant shock. The operator must, however, determine the exact level of the cord to be sectioned and the exact area of the cord to be destroyed.

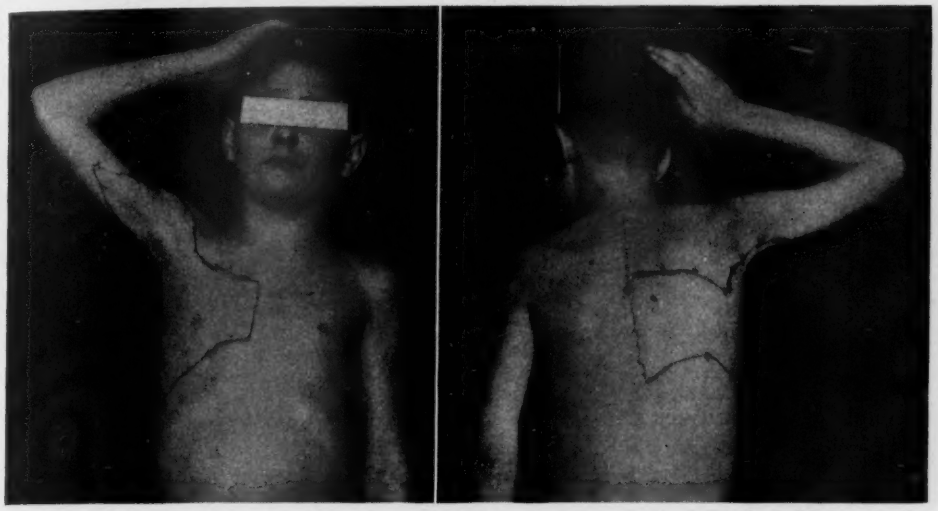

Fig. 7. Case 1. Showing postoperative scar and area of anesthesia following rhizotomy for intense anginal pain referred to the right upper arm and chest. Complete relief of pain with area of anesthesia outlined by skin pencil.

With the recognition that the pain mechanism concerns primarily two great systems, (a) the peripheral nerve pattern and (b) the vascular tree, the need of careful questioning relative to the character of the pain and its distribution will be further apparent.

In the majority of instances, the patient should be able to trace the pain distribution and direction, so that the examiner may be able to detect at once the anatomic characteristics of nerves or vessels. The visceral organs follow certain reflex segmental pain arcs which are familiar and easily recognized.

Where nerves and vessels are closely associated, as in the axilla and the groin, differential tests must be applied. Here the neurologic examination, as it concerns the pain mechanism, is simple and informative. The ascending spinal anesthesia test can be employed in cases of doubt.

Problems concerned with the peripheral nerves, where trauma or selective involvement gives rise to characteristic sensory patterns and pain reference have been dealt with in detail by Davis and Pollock,[3] Babcock[4] and others. Of more interest and concern, from the standpoint of this paper at least, will be those conditions of pain reference which offer difficulties in recognition, diagnosis and treatment.

Lesions involving the pain pathways of the cord (spinothalamic tract or anterolateral column) which may project their symptoms into the extremities, lesions of the nerve roots within and without the canal, pains of visceral origin (cardiovascular, sacral, pelvic) which find reference into the arms and legs, certain intractable states of pain following amputation of a member—all these require special consideration as to diagnosis and treatment.

If rational measures of relief are to be applied, then an exact knowledge of the pain structures involved and the pathways by which these impulses reach the brain must be established.

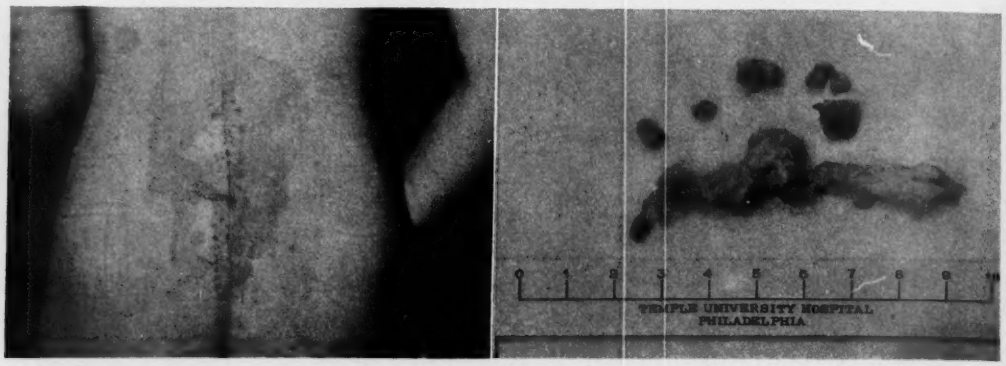

FIG. 8. Postoperative wound ten days after removal of nucleus pulposus. Patient considered a case of sciatica until myelogram disclosed defect in spinal canal. Fibrocartilaginous material removed.

The following physio-anatomic facts briefly enumerated will aid in clarifying the problem.

In order that an individual feel and appreciate pain, the thalamus must be intact. Central irritation at this level gives rise to widespread contralateral *hyperalgesia* and often burning pain; lightly touching the skin surface may be highly painful and although projection may occur into an arm or leg, it is usual to find tendencies to include body areas as well, and hemilateral syndromes may be present.

Above the thalamic level, painful sensations are integrated, evaluated and localized by the cerebral cortex. In order that pain may be described, localized and appreciated by the individual, *consciousness* must be present, and, furthermore, there must be attention or concentration of the patient upon the painful sensations. It is well known that painful processes exist, but may be ignored or actually not appreciated, if *attention* is or can be diverted. The child engrossed in play may receive a painful cut or bruise and remain "unconscious" of this fact until bleeding or some other incident attracts attention to the area involved, pain then is fully appreciated. If the same amount of injury were to be deliberately inflicted with the individual's attention concentrated upon the act, the experience would be one of extreme suffering and reaction.

Thus, many factors may truly alter the circumstances surrounding pain, as many patients may "concentrate on" or "ignore" their pain processes. Too frequently even well trained examiners hastily conclude that certain patients belong in the "functional group" or term their complaints due to "psychalgia" when no readily apparent reason for the pain can be disclosed. It is true that certain races and individuals bear pain more stoically than others. This is readily demonstrable during certain steps in an exploratory craniotomy. I frequently find it necessary to resort to "local" and "vocal" anesthesia where a general anesthetic would be undesirable or contraindicated. Especially is this so when dealing with cerebellar tumors in children.

In the Nordic, the Angle and the Saxon types, attention is easily diverted and painful steps accomplished without much complaint by means of "vocal" anesthesia or forced conversation with the patient during operation. In the Dravidian and Semitic types, the same procedures and methods are associated with definitely greater responses and suffering.

The cases here presented all illustrate problems of pain, in which, for one reason or another, there was a failure to find relief from the usual sources. These patients had been discarded into the "neurotic" or

"functional" group, with little hope of salvage. The fact that these pain problems proved to be demonstrably real and curable only serves to warn us against attempting to evaluate the patient's suffering until we have an intimate understanding of his background, personality, meaning of symptoms and the pain pathways which carry the impulses to a stoical or self-conscious brain.

Fig. 9. Myelographic study of the lumbosacral region. Note normal cigar-shaped canal when filled with air (outlined by dots). Characteristic defect caused by a protrusion of the nucleus pulposus with compression of the fifth lumbar and first sacral roots, simulating sciatica, indicated by arrows.

CASE REPORTS

Case I. L. C., age 13 was referred by the Medical Department November 30, 1937.

Diagnosis: Aortic regurgitation and stenosis with severe anginal attacks. Pain radiating across right breast and inner side of the arm to the elbow.

Operation: Exploratory laminectomy with rhizotomy done December 6. Section of the second, third and fourth posterior roots on the right.

Result: Patient made a prompt postoperative recovery. Entirely free from pain for first time since onset of attacks two years before. Anesthesia, inner arm and upper chest. (Fig. 7.)

This case serves to illustrate the root level (T_2, T_3 and T_4) where the major portion of vascular pain fibers from the heart and aorta enter the cord. Section of these roots brought about complete relief of pain.

Case II. H. S., age 57, was referred by Dr. W. A. Steel and admitted August 18, 1935.

Diagnosis: Painful stump ("amputation neuroma") following removal of the right leg for Buerger's disease.

The patient suffered burning, constant pain in the stump with some projection to absent toes. The stump was very sensitive. The patient cried and moaned continuously, and required narcotics. He had had *section of the sciatic nerve, section of the anterior crural nerve, injection of the lumosacral roots, paravertebral injections.* Pain persisted in the stump although the skin surface was anesthetic.

The ascending spinal anesthesia test showed *complete anesthesia to below the umbilicus* (T_9), but the stump remained painful and deep pressure caused intense pain. *Complete anesthesia to below the nipple line* (T_6) left the pain persistent in the stump, but rendered manipulation less painful. *Complete anesthesia to the*

axilla (T_3) made the patient entirely free of pain. No pain occurred on deep pressure or manipulation of the stump. Diagnosis was

Diagnosis: Sciatic neuritis, left.

For past four years, the patient had had a dull, aching pain in the left lower extremity.

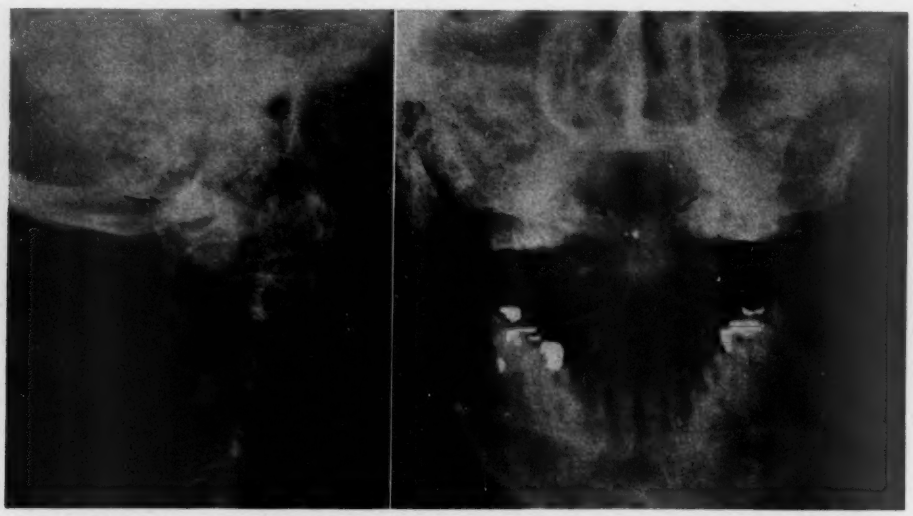

Fig. 10. Olive-shaped calcified tumor seen within the spinal canal and projecting through the foramen magnum. Arrows indicate its size and location when seen through the mouth. Turning of the head produced pain in the right occipital area and left leg. See Case iv. (*X*-rays by W. E. Chamberlain.)

therefore vascular pain, fibers entering T_3, T_4 and T_5. Recommendation: Chordotomy at T_1.

Operation: Exploratory laminectomy for chordotomy was done August 21. Exposure of cord below the seventh cervical and first thoracic lamina was followed by section of the anterolateral column on the left side.

Result: Patient made a prompt postoperative recovery. Relief of pain with correction of narcotic habit followed. He has been pain-free three years and five months—to the present time.

This case serves to illustrate the value of the ascending spinal anesthesia test in a patient who was thought to be a case of psychalgia, because apparently all the sensory nerves to the leg and stump had been destroyed and the skin was anesthetic, but still he complained of pain. Entry of vascular pain fibers from the lower extremities occurs chiefly into roots T_3, T_4 and T_5. The cause of pain in this instance was probably further pathology or irritation of the arterial tree above the level of amputation.

Case iii. S. G., age 22, was referred by Dr. John Royal Moore and admitted April 26, 1937.

The pain was worse when walking, standing, coughing or sneezing. An Ober fasciotomy and transection of the pyriformis, left, had been done in January, 1937 with only slight relief.

Myelogram: "There is a deformity along the left side of the canal, at the level of the lamina of the fifth vertebra. This deformity consists of a rounded prominence which protrudes into the subarachnoid space." (Fig. 9.)

Operation: Exploratory laminectomy of the lower lumbar region was done May 13. A tumor about the size of an almond, situated at the left side beneath the fifth lumbar lamina and anterior to the root of exit, which proved to be nucleus pulposus, was found. (Fig. 8.)

Result: Patient made an uneventful postoperative recovery and was free from pain upon discharge. (Fig. 8.)

This case serves to emphasize the importance of visualizing the spinal canal by means of oxygen or air when root pathology is suspected. The defect was readily seen (Fig. 9) and the protruding disc material removed (Fig. 8) at operation.

In spite of the frequency with which the diagnosis of sciatica is made, in my experience true sciatica is extremely rare and "double sciatica" almost invariably denotes a cord lesion. What is so frequently

called "sciatica" is either root or peripheral compression. This diagnosis always calls for careful and complete neurologic studies.

Case IV. Mrs. L. B., age 78, was admitted December 20, 1935 with a diagnosis of high cervical pain.

The patient had been to thirty-three doctors, including several specialists. She complained of pain in the back of the head, on the right side, and burning, shooting pain in the left leg. One of the leading neurologists had made the diagnosis of "occipital neuralgia" on the right side and "Buerger's disease" of the left leg.

The patient had the pains simultaneously and usually when she turned her head to the right and upward. There was slight decrease in pain and temperature perception of the left leg and distinct impairment of sensation over the occipital area and angle of the jaw, on the right (C_2 and C_3). Aside from this, the patient had no other neurological findings.

A lesion involving the right anterolateral column was predicted at the level of the atlas. Special *x*-ray studies were requested and the films (Fig. 10) were quite diagnostic. The pain reference in this case to the opposite lower extremity was characteristic of spinal cord irritation.

Result: Exploratory laminectomy, under local anesthesia was done on December 30. A calcified meningioma, the size of an olive, was removed. Postoperative recovery was prompt the patient has been pain-free and well for the past three years; she travels extensively and carries on her lecture work at 81.

This case serves to illustrate a central form of pain projected into an extremity and not to be confused with local "cramps" or disease of an extremity. The sharp root pain to the occiput was intense enough to be considered a neuralgia, and in a traumatic sense it proved to be of the compression type.

SUMMARY

Pain reference into the extremities may be of nerve, root, or cord origin. When a distinct peripheral nerve pattern cannot be established, the clinician must analyze the character and location of the pain to determine whether it is anatomic to the nervous structures or whether it follows the vascular pattern. Appropriate measures for the relief of pain will depend upon the structures involved.

The ascending spinal anesthesia test and careful neurologic studies may be required before determining what surgical method to use.

A patient claiming to suffer pain should not be classed as a "functional" or "psychalgic" type merely because the mechanism of pain is not at once obvious.

Satisfactory results from surgical measures, for relief of pain, can only be expected when the pain mechanism and its pathways are clearly understood and interruption of the proper fibers at the proper levels carefully undertaken.

REFERENCES

1. Fay, Temple, and Gotten, N. Controlled spinal anesthesia. *Arch. Neurol. & Psychiat.*, 30: 1276–1281, 1933.
2. Spiegel, E. The mechanism of pain. *Internat. Clin.*, 3: 141, 1938.
3. Pollock, L. J., and Davis, Loyal. Peripheral Nerve Injuries. New York, 1938. Paul B. Hoeber.
4. Babcock, W. W. Textbook of Surgery, 2nd. Ed. Philadelphia, 1935. W. B. Saunders Co.
5. Fay, Temple. Localization and treatment of lesions of the spinal cord. *S. Clin. North America*, pp. 1577–1597 (Dec.) 1938.

NERVE GRAFTS

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IT is often questioned whether or not free nerve grafts are of practical value and on this there is considerable difference of opinion ranging from the conviction that they are useless to the belief that they are successful. In this paper an attempt is made to contribute data from both our experimental and our clinical experience with autogenous nerve grafts.

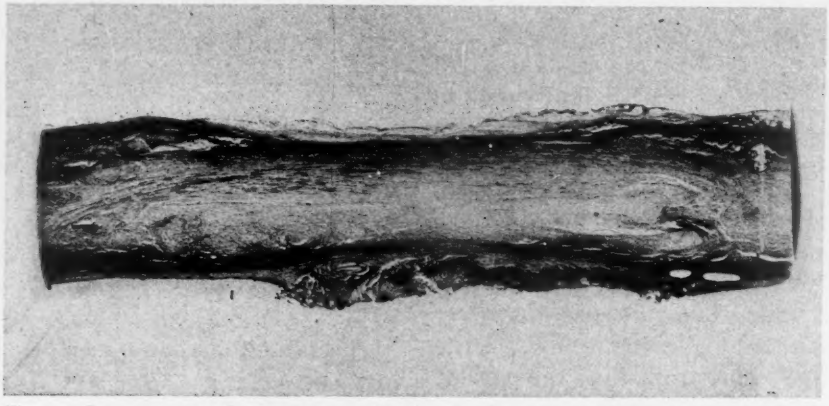


FIG. 1. Low power photomicrograph of a fresh autogenous nerve graft in the sciatic nerve of a cat four weeks after the operation. To the left is the proximal nerve, to the right the distal nerve. Between the two bits of sutures lies the graft. The new axons stain black. The gradually decreasing number as one approaches the distal end is apparent.

Autogenous grafts of various kinds including the so-called prepared grafts were made in cats by Joseph H. Boyes in a series of experiments. These were later checked microscopically to determine the down growth of axones.

Also, in a series of thirty-two autogenous nerve grafts done by Sterling Bunnell in twenty-one patients, the results are listed.

Review of Nerve Repair. When a nerve is severed both ends undergo a change. In the proximal portion connective tissue soon caps over the end, forming a barrier to the downward growth of axones. The nerve trunk swells above the severance as each axone splits into many fibrils each of which grows downwards seeking the distal nerve end. Thus bountiful Nature provides fifty times the normal number of nerve fibers in hopes that enough will find the way. Most of them curl up in the scar cap, forming a bulbous neuroma, but a few grow through into the surrounding tissue. If the gap between the nerve ends is over 2 cm. very few fibers ever find the distal nerve end.

Meanwhile the distal portion of the nerve swells from the proliferation of the cells of the sheath of Swan. The myelin disappears, the axones fragment and absorb, and protoplasmic strands known as bands of Bungner form through the length of the nerve. These later act as guides for the axones that grow down from the proximal portion of the nerve. This Wallerian degeneration occurs in two weeks. The cut end becomes capped over by a growth of nerve connective tissue as a small glioma in contrast to the large neuroma terminating the proximal fragment.

Nerve ends, when repaired by suture, should first be trimmed back, not timidly so that on the cut surface one sees only a mixture of connective tissue and axone bundles, but boldly until only clear cut

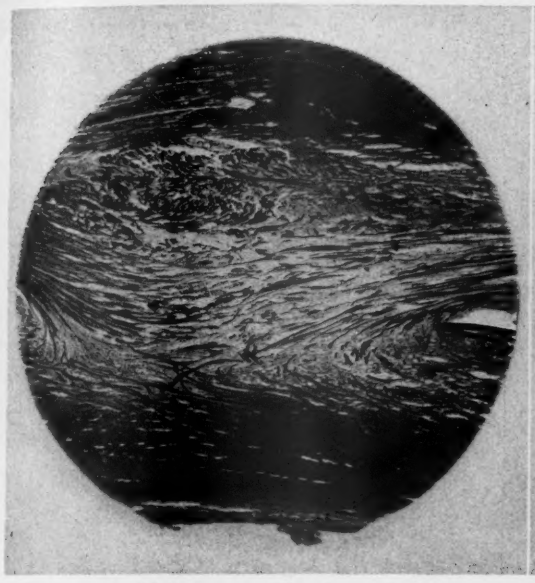


Fig. 2. A higher magnification of Figure 1 showing the proximal suture line. A bit of suture appears at 3 o'clock.

Fig. 3. A section of the proximal suture line of a fresh autogenous graft in the sciatic nerve of a cat six weeks after the operation. At the lower edge are seen the coarse fibers of the proximal nerve; nearer the center, the fibers have become turned back in their course and at the left center some have completely reversed direction. The many spiral tubes called Perroncito apparati are an indication of obstructed growth, in this case due to folding back of nerve tracts; an example of poor approximation.

Fig. 4. A section through the mid-portion of a degenerated nerve graft in the sciatic of a cat four weeks after operation. The proximal nerve is to the left. Note that the central core has fewer fibers and that it still contains necrotic products because the graft has not yet developed a good blood supply in the central portion. This explains the failure of grafts of large diameter.

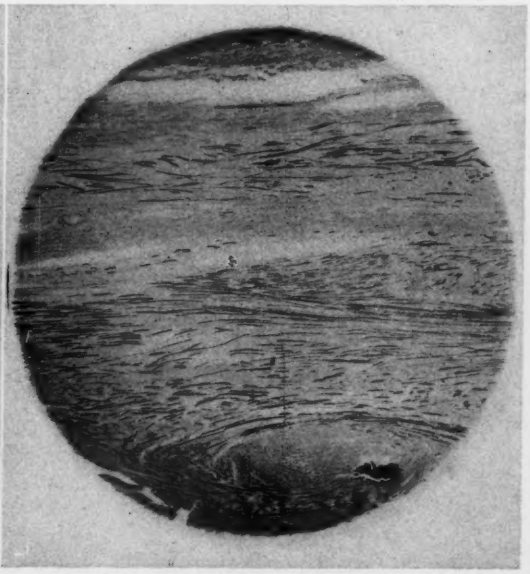


Fig. 5. A section of the distal suture line of a degenerated nerve graft in the sciatic of a cat four weeks after operation, showing nerve fibers crossing the scar joining the nerve graft to the peripheral nerve. A bit of suture at 5 o'clock marks the level of the anastomosis.

axone bundles definitely present. The suturing by the finest blood vessel silk or Deknatel A is through the sheath only and should maintain the nerve ends squarely and exactly together with the opposite axone bundles in contact with each other. There should be no gap in the sheath allowing axones to escape and become lost and no gaps between the nerve ends for accumulation of cicatrix which acts as a barrier. Axones will then grow down the bands of Bungner at the rate of from 1 to 1.5 mm. a day. At first they are nonmyelinated and as they grow down give tingling on tapping which later stops as they become myelinated.

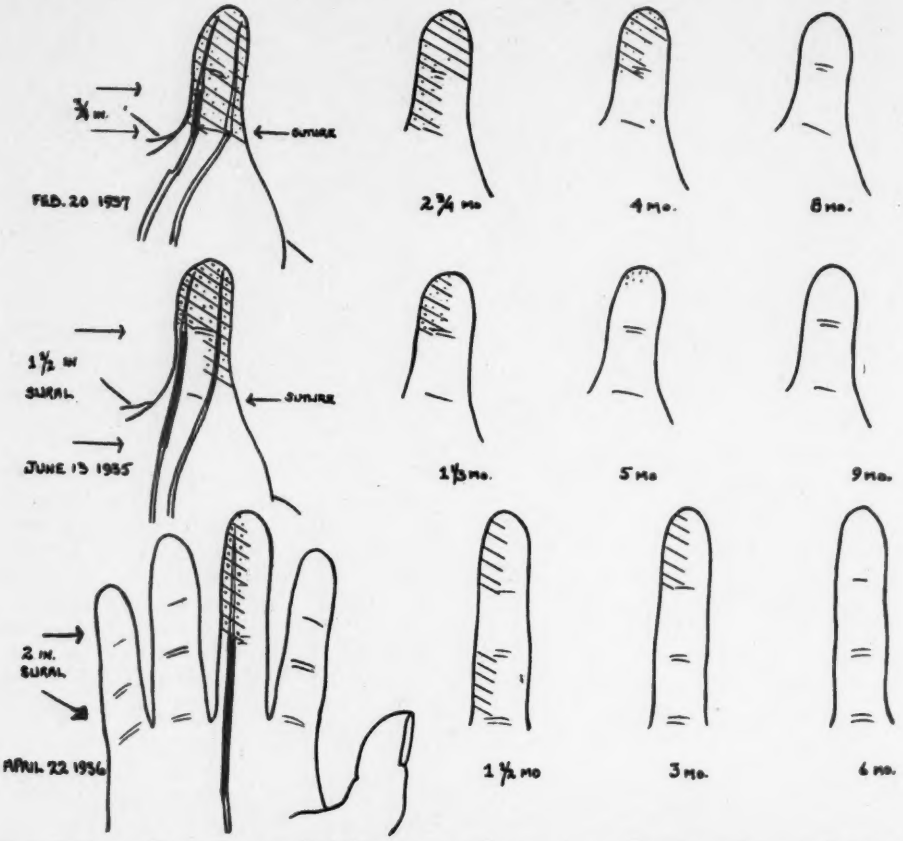


Fig. 6. Upper Row. Case A. S. Nineteen months previous a band saw lacerated across the proximal crease of the thumb. Infection followed, resulting in ankylosis of the proximal joint and loss of the flexor tendon and nerves. The contracture was relieved by zigzagging the scar in the web and repairing the nerves. The nerve to the radial side was sutured while that to the ulnar side was repaired by a free graft taken from the same nerve trunk higher up. Sensation returned to the pulp in eight months.

Middle Row. Case R. B. Six months before a broken bottle had lacerated the right thumb severing both volar nerves and the flexor tendon. The resulting flexion contracture was relieved by plastic swinging of skin flaps. The nerve to the radial side was sutured at the proximal crease and a 1½ inch gap in the nerve to the ulnar side was closed by a free graft from the sural nerve of the right leg. Sensation returned on the radial side in one and one-third months and on the ulnar side in nine months.

Lower Row. Case J. D. Five and one-half months after an infection of the long finger had destroyed the nerve to the ulnar side of the finger over a distance of 2 inches, the nerve was united by a free graft from the sural nerve. Sensation returned in six months.

The degree of regeneration is in direct proportion to the accuracy of the union.

It should be kept in mind in judging from the literature the value of nerve grafts that many useless illogical methods of nerve joinings have been in common use which

could not yield good results. Thus nerve junctures have been made by end-to-side implantation, by turning down nerve where it will do most harm. Smearing with vaseline provokes a very bad tissue reaction. Inaccurate suturing and leaving a

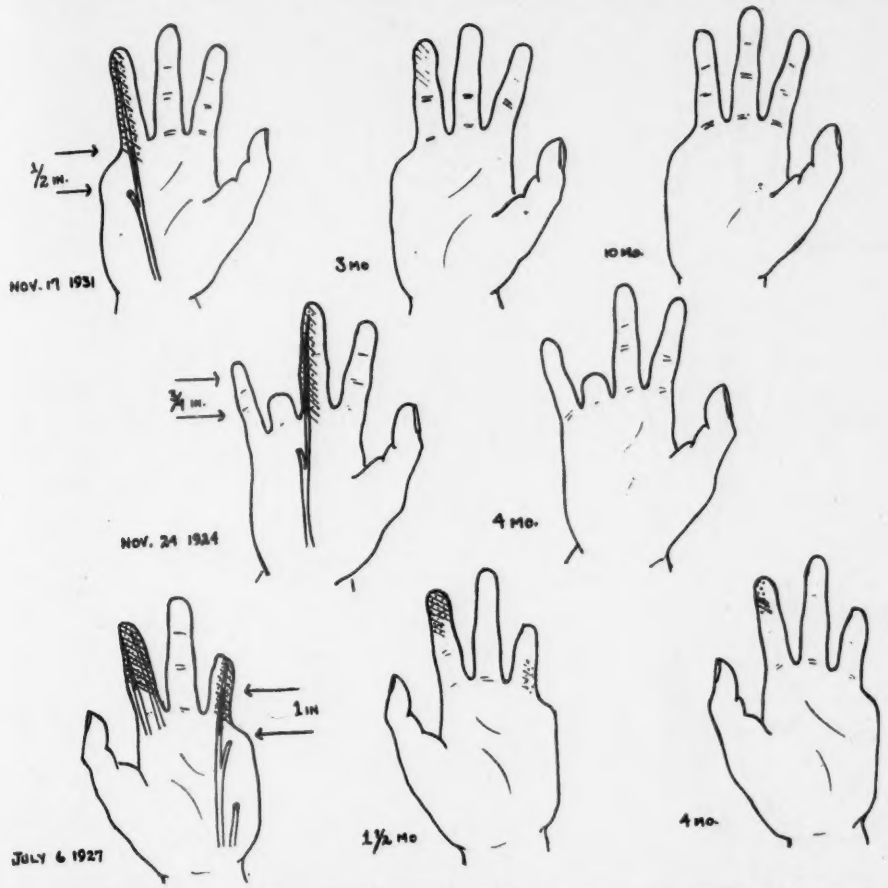


Fig. 7. Upper Row. Case O. E. Eight months after an aeroplane propellor half severed his right hand, a ½ inch gap in the volar nerve to the ulnar side of the ring finger was closed by a free nerve graft from an adjoining stump of the little finger. Sensation was complete in ten months.

Middle Row. Case H. D. N. Sixty-nine days after a steam shovel had amputated the ring finger and removed a segment of the volar nerve from the adjoining side of the long finger, the ¾ inch gap in the nerve was bridged by a free graft from the radial volar nerve of the amputated finger. Anesthesia to cotton touch and pin prick left the long finger in four months.

Lower Row. Case D. E. Six months after a circular saw lacerated the hand and after a severe subsequent infection, the nerves to the index finger were sutured at the level of the middle joint and an inch gap in the nerve to the ulnar side of the ring finger stump was filled by a free graft taken from the volar nerve to the little finger stump. Sensation was almost complete in four months.

flaps, by sutures at a distance with catgut strands between or a segment of blood vessel, none of which make an end-to-end union of the axone bundles. Also nerve junctures have been wrapped in cargile membrane or other foreign body or placed inside of a segment of blood vessel which effectively block blood supply from surroundings and add excess of scar tissue nerve suture in a bed of scar tissue instead of displacing it into normal soft tissue will result in strangling cicatrix at the juncture. Therefore, the technique of suture should be weighed in evaluating the results from nerve grafting.

Overcoming Gaps in Nerves. Quite a long gap in a nerve can be overcome and the ends of the nerve brought together for

direct suture if we use all the means at our command. In most nerves much length can be gained by freeing them in various places from the surrounding tissues and gently drawing upon them when the joints are flexed. Care must be used not to overpull a nerve or to pull off motor branches as it passes between the muscles. All joints may be flexed if necessary from the trunk to the end of the limb. After a month when the nerve ends have united, the limb is gradually extended over several weeks so the nerve will have time to grow to its full length again. In some nerves as the ulnar, radial and facial, length can be gained by transposition.

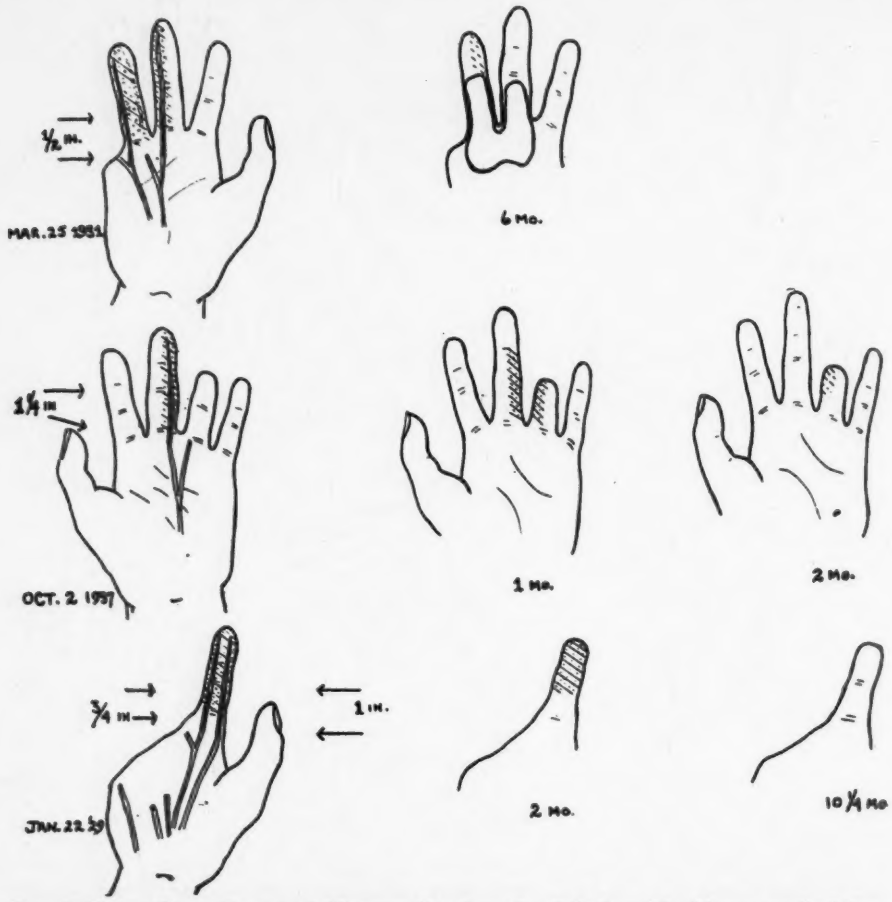


Fig. 8. Upper Row. Case A. J. Six months after the right hand had been crushed in a fly wheel, exploration showed the nerve to the radial side of the ring finger destroyed beyond repair and a ½ inch gap in that to the contiguous side of the long finger. A free nerve graft was taken from the proximal portion of the more severely damaged nerve to the ring finger, and the whole area was covered by a previously prepared tubular pedicle from the abdomen. Six months later sensation was present over the complete area of the long finger.

Middle Row. Case H. S. Three and one-half months after a saw lacerated the left hand, severing the nerve on the ulnar side of the long finger and amputating the tip of the ring finger, the stump of the ring finger was revised and a 1¼ inch gap in the nerve to the long finger was filled by a free graft from a nerve to the ring finger stump. Sensation returned in two months.

Lower Row. Case E. M. D. Five months after a buzz saw cut across the hand obliquely from the base of the fifth metacarpal to the side of the index finger, the cicatricial index finger was amputated through the middle joint and ¾ inch and 1 inch gaps in its two volar nerves were repaired by free grafts from the adjoining volar nerves in the palm. Sensation was complete in the stump of the index finger in eleven months.

If after an attempt to approximate nerve ends by the above methods, they still will not reach each other, they should be sutured there to the surrounding tissue. Then, after gradual stretching as above, a second operation should be done. The ends of the nerve may at that time reach each other.

Occasionally a nerve in an amputation stump is available to suture into the distal portion of the severed nerve as a nerve transfer or it may be that a muscle transfer is possible to relieve disability.

Failure of these methods leaves free nerve grafting as the only procedure available. Therefore, its limitations and its values should be known.

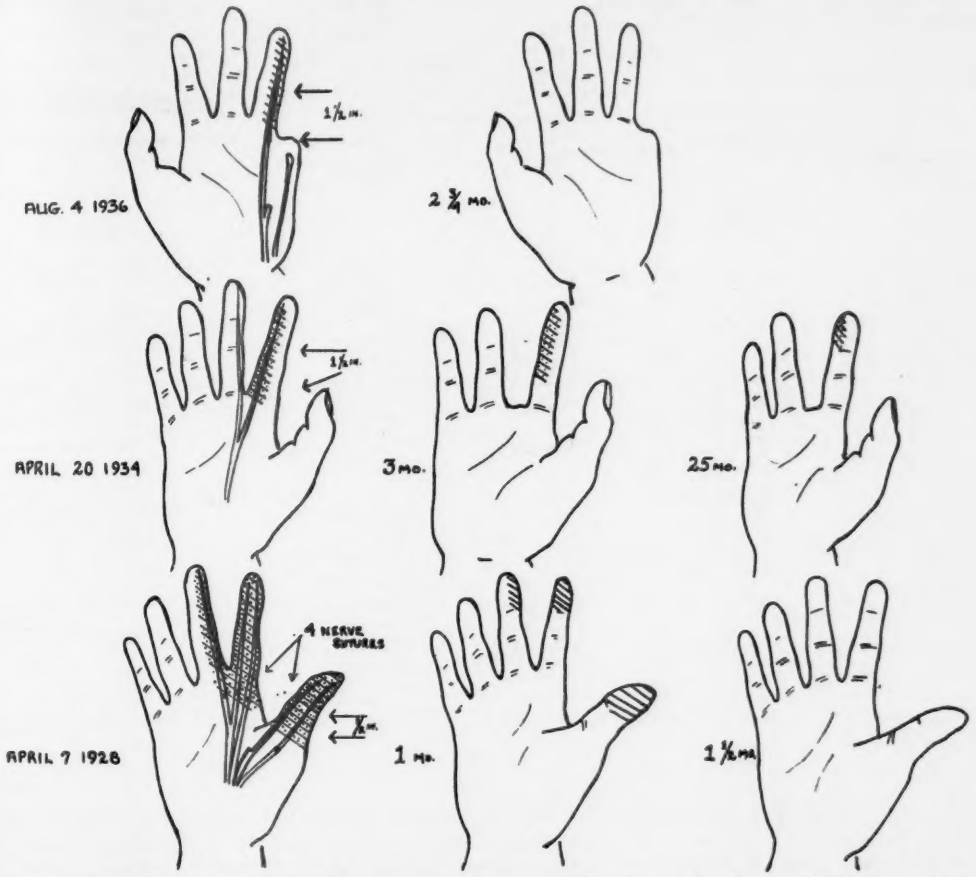


Fig. 9. Upper Row. Case P. L. Three years and two months after a circular saw had amputated the little finger and severed both tendons and one nerve of the ring finger, a 1½ inch gap in the nerve was bridged by a free graft from the nerve to the stump of the adjacent little finger. Sensation was complete in 2¾ months.

Middle Row. Case L. S. Seven months after severe tenosynovitis destroyed the right long finger and severely crippled the hand and four months after the wounds finally healed, a 1½ inch gap in the volar nerve to the ulnar side of the index finger was replaced by a free graft from one of the nerves of the amputated long finger. Sensation returned rapidly up to a time two years from operation when a small area of anesthesia was still present on the tip. Atrophy of the skin cleared, however, and sweat glands again functioned in this area.

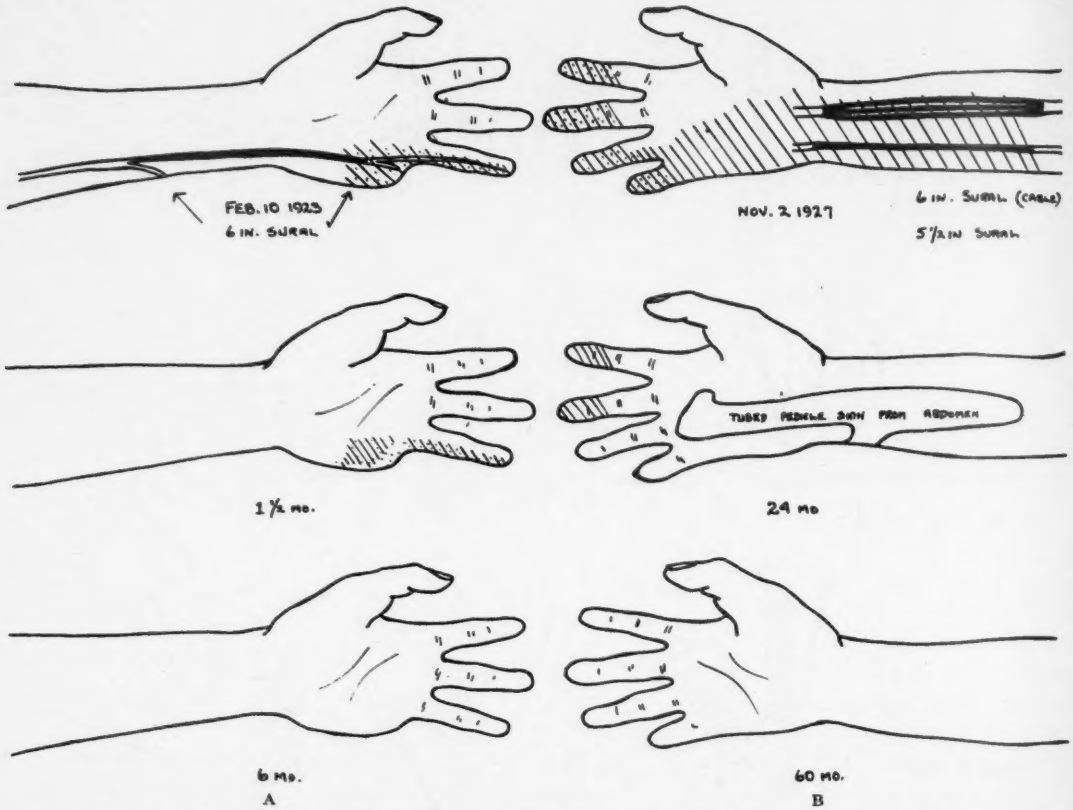
Lower Row. Case F. LaP. Ten weeks previously the flexor tendons in the right thumb and index finger and five nerves were severed when she fell on a milk bottle. Four nerves were sutured, but that to the ulnar side of the thumb was too short. Therefore, a ½ inch segment was removed from its proximal end and used as a free graft to join this nerve. Sensation was complete in 1½ months.

Literature of Nerve Grafts. Following the first description of the use of a nerve graft by Albert in 1878 a few isolated case reports appeared in the literature, but it was not until the time of the World War

that reports were made of any appreciable number of nerve grafts together with their end results.

these was much less than through fresh autografts.

Cajal and Forssmann postulated a chemo-



A B

Fig. 10. A, Case J. B. K. Eight months after a laceration of the wrist from a broken windshield and subsequent infection had resulted in an amputation of the little finger and loss of the ulnar nerve, a 6 inch sural graft was placed in the nerve as in the diagram. In five months sensation to touch and pin prick could be felt throughout. The ulnar motor branch had not been sutured.

B, Case S. T. Eleven months after a blast from a shotgun and subsequent infection had gutted the right forearm of tendons and nerves and after good skin had been supplied by a tubular pedicle from the abdomen, the median nerve was repaired by a three ply 6 inch graft from the sural nerve and the ulnar nerve was united by a single strand 5½ inches long. Five months later flexor tendons were supplied to all digits, a "pulley" operation for opposition of the thumb was performed and the radial nerve was sutured. Five years after the first operation sensation was present throughout.

Platt's report in 1919 of a series of twenty cases of nerve grafts with complete failure in all gave rise to the note of scepticism among British surgeons which has since pervaded the English literature on the subject. In this series, however, it should be noted that only single nerve strands were used instead of cable grafts and these were enclosed by fascia or vein.

Huber concluded that experimentally autografts were successful and, though some regeneration occurred through other types of fresh grafts as well as preserved grafts, the degree of regeneration in

tactic influence in a degenerated nerve which attracted the newly growing fibers from the proximal stump, although Dustin and Huber failed to find basis for this theory.

Balance and Duel used fresh and prepared autografts in repair of the facial nerve and reported their results in a series of articles from 1931 to 1936. In experiments on monkeys they reported that they had obtained regeneration in prepared, that is, previously degenerated nerve grafts in one-half to one-fourth the time necessary for that in fresh autografts. This we do not

believe because of our own experimental findings and those of Bentley and Hill in 1936. The latter reported a series of

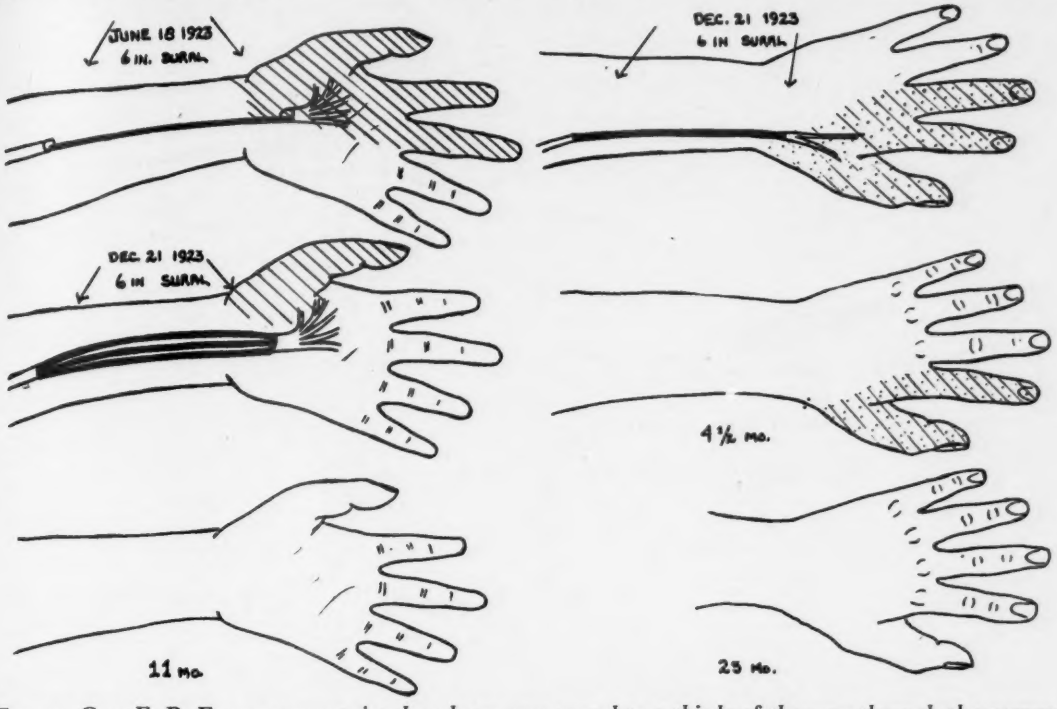


Fig. 11. Case E. B. Four years previously a buzz saw passed two-thirds of the way through the carpus from the radial side, and during the subsequent infection a considerable length of the median and radial nerves sloughed out. On January 18, 1923, a single strand of sural nerve was used to unite the median nerve in the forearm. Six months later some sensation had returned and therefore two other strands were placed in the median nerve and one strand was used to unite the radial nerve. Eleven months later he felt touch and pinprick over the whole arm. In one and one-half years stereognosis had returned.

experiments with the so-called prepared or previously degenerated nerve grafts and concluded that there was no essential difference in the rate of down growth of axones through fresh autogenous grafts or previously degenerated ones.

Our Experimental Work. To determine the regeneration following fresh auto nerve grafts compared with that following predegenerated nerve grafts, two series of cats were studied.

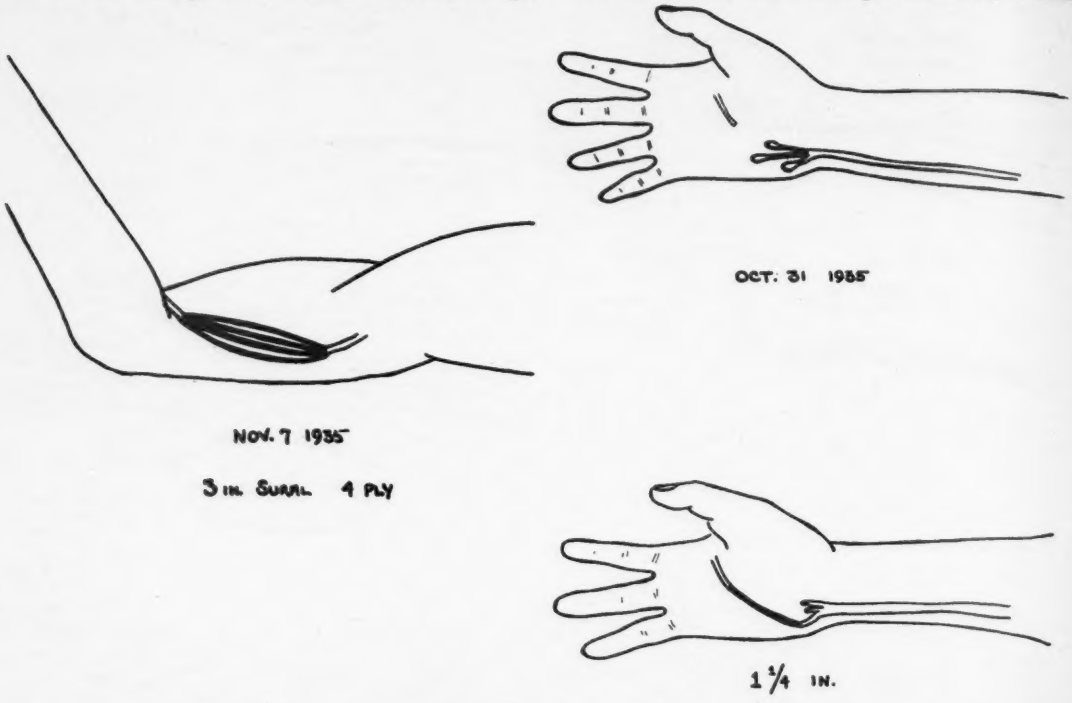
In the first series four cats were used. In each a 2 cm. length of sciatic nerve was cut out, reversed end-for-end, and sutured back into place. After intervals of two, four, six and nine weeks respectively, the cats were killed and longitudinal microscopic sections of each nerve and graft were studied.

In the second series of three cats the sciatic nerve was first severed and degeneration of the distal portion was allowed to progress for two weeks. Then in each a segment from the distal portion was cut out, reversed end-for-end and sutured into continuity with the nerve just as in the first series. The specimens were examined, one in two weeks, another in four weeks and the third in six weeks after operation.

It was found that in two weeks in both the fresh and the degenerated grafts new nerve fibers had already penetrated the full length of the graft and were entering the distal nerve. At four weeks the fibers had increased in number in the grafts and had reached past the second suture line and well into the distal nerve. At six weeks regeneration had progressed further but myelin did not appear until in the specimen obtained after the eighth week.

We concluded that there was no difference in the rate of growth of nerve fibers through fresh and predegenerated auto nerve grafts.

It is interesting to note that the regeneration of nerve fibers was largely in the peripheral zone of the grafts. Here surrounding lymph penetrated sufficiently to maintain vitality while the central portion of the graft showed some necrosis. This argues for either small or cable grafts instead of thick ones.



A B

Fig. 12. A, Case F. L. H. Twenty-two and one-half months after a compound fracture of the humerus, received when an oil drum exploded and wrapped its ends around the patient's left arm, and five and one-half months after all osteomyelitis had healed, the musculospiral nerve was bridged by a four ply cable graft 3 inches long from the right sural nerve. Only an inner slip of the triceps had remained innervated. Eighteen months later anesthesia disappeared from the hand and voluntary motion was present in the extensors of the wrist and extensor pollicis longus. Examination three years after operation showed absence of anesthesia and good power to extend fingers and thumb, even with wrist passively held dorsiflexed, but only a little of voluntary dorsiflexion of the wrist. The nerve pathway for dorsiflexion of the wrist was evidently mechanically missed by the down-growing axons, as it is the only nerve branch that did not regenerate and this branch of the radial nerve is usually the first to regain function.

B, Case T. S. Four years before, he fell on a glass, severing the ulnar nerve and flexor tendons to the ring and little fingers and opening the wrist joint. Infection followed an attempted primary repair and lasted two months. At operation on October 31, 1935 (performed at meeting of American College of Surgeons) the little finger was amputated including its metacarpal. Its extensor tendon was transferred to the adductor of the thumb, its flexor to the interossei of the ring finger and a 1¼ inch gap in the deep motor branch of the ulnar nerve was closed with a graft from one of the sensory branches of the ulnar. Twenty months later the interossei recovered and their atrophy had disappeared. He could adduct the straight thumb to the same degree as in the opposite hand.

Clinical Report and Discussion. In the following series of thirty-two nerve grafts done over a period of fifteen years we have endeavored to keep accurate pre- and postoperative notes and to present a true picture of the results. Two additional cases which could not be followed postoperatively are not included. The technique used was uniform, accurate perineural or sheath suturing with the finest silk and without any intubation by free fat, membrane or foreign body placed around the juncture. The nerves sutured were, wherever possible, merely placed in soft vascular tissue as free from cicatrix as possible.

Grafting was used only where the methods of achieving end-to-end union were exhausted or were inadvisable. Only those nerves were sacrificed for grafts whose function was of less importance than

was the function to be gained. The sural nerve from the center of the calf was usually the graft of choice. The area of resultamputation distal to it had rendered the nerve functionless. It is neither necessary nor justifiable to sacrifice motor function to

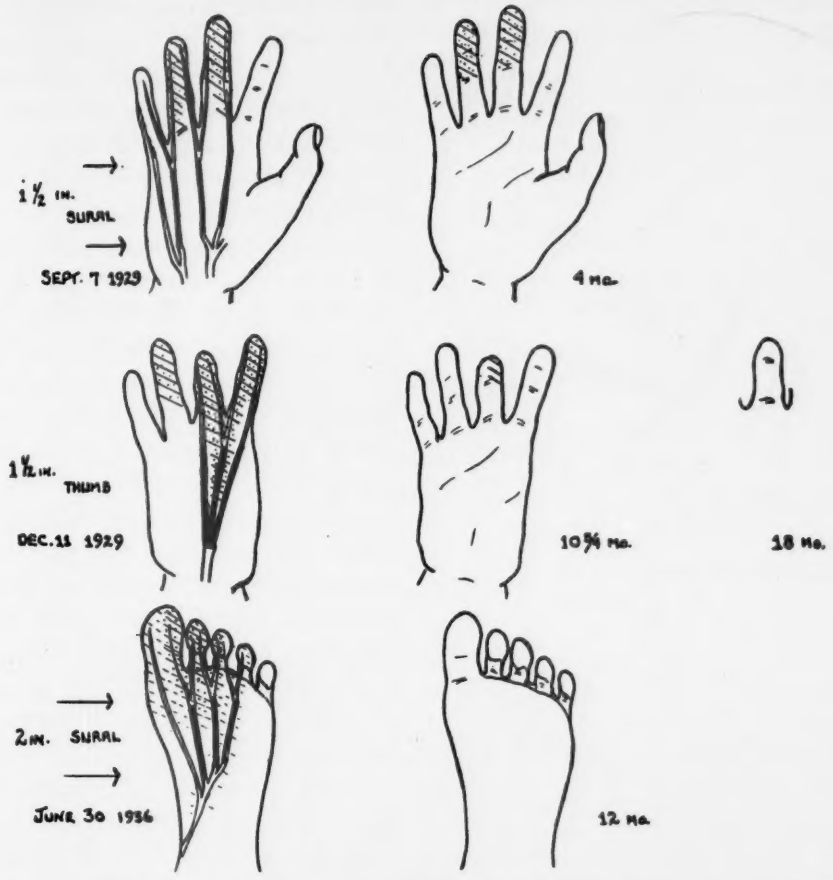


Fig. 13. Upper Row. Case A. T. Four and one-half months previously a saw cut the right palm, severing tendons and nerves. After two operations had been done elsewhere, the 1½ inch gaps in the volar nerves to the second, third and fourth clefts were closed by free grafts from the left sural nerve. In four months sensation had returned except over the area shaded above, after which he did not return for subsequent examinations.

Middle Row. Case W. A. D. Nine months after the right hand was caught in a kale cutting machine, amputating the thumb and a portion of the long finger and severing all the flexor tendons except the little, and seven months after the infection had subsided, the nerves to the index and long fingers were repaired by three free nerve grafts, one of which was made up of two segments of free nerve ends dissected from the scar in the palm. The remaining two grafts were obtained from the original thumb branches, split from the main trunk of the nerve. Sensation was present throughout eighteen months later.

Lower Row. Case E. W. Ten and three-fourth months previously she stepped on a broken bottle, lacerating the sole of the left foot. At operation a gap of 1½ inches in the flexor hallucis longus tendon was bridged by a free tendon graft. Each of three branches of the internal plantar nerve had a 2 inch gap in it which was filled by free grafts from the sural nerve of the opposite calf. One year later sensation was present throughout and motion had returned to the great toe.

ing anesthesia from loss of this nerve is small, if any, and patients as yet have not complained. Occasionally a part of some other nerve was available because an procure a nerve graft. Sensory nerves as grafts have been shown to convey equally well motor or sensory axones when placed in the normal direction or when reversed

end for end. The sural nerve is nearly always available. It is just beneath the mid vein of the calf; in the upper part of the calf it is under the deep fascia and in the lower part is superficial to it. Of other available sensory nerves the cutaneous branch of the radial, if severed, often leaves a most tender neuroma. The internal cutaneous and sensory branches of the femoral are rather small. The long saphenous, if removed, causes some anesthesia. The sural, therefore, is the nerve of choice. Almost a foot of this nerve is available from each calf, allowing ample material even for a cable graft into a fairly thick nerve.

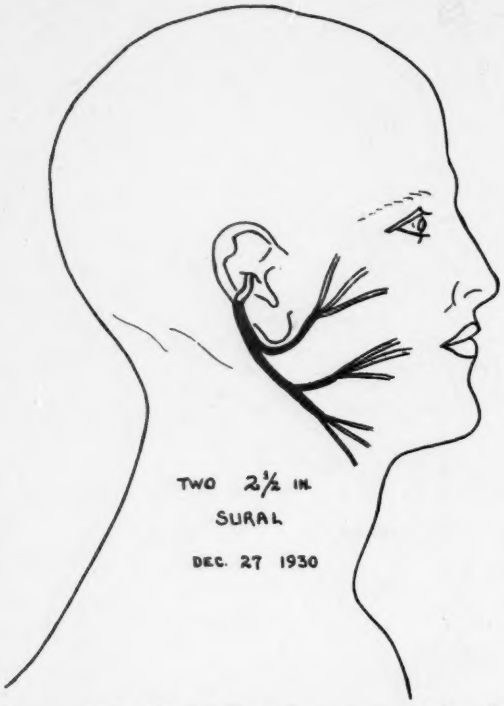


Fig. 14. Case M. B. Two free nerve grafts 2½ inches long, one of which was branched, were used to repair a facial nerve which had been invaded by a tumor of the parotid gland. Some voluntary motion first appeared in six months, increased in nine months, and in seventeen months symmetry of the face was regained. The tumor later recurred and was excised with the nerve graft en bloc. Sections showed that nerve fibers had grown through the graft into the distal portion of the nerve. This is the first case in which a free nerve graft was used to repair the facial nerve. (Reported in detail in *Arch. Otol.*, 25: 235–259, 1937.)

In our series the results are uniformly good in all of the cases that could be traced, apparently for the following reasons: In this series the nerves grafted were either small in diameter (as the facial nerve or nerves in the hand) or if larger, cable grafts were used made up of multiple small strands of nerve grafts amounting in the total cross section to the size of the nerve itself. These slender stranded nerve grafts were readily kept nourished through and through merely by lying in the surrounding lymph until they acquired a blood supply of their own. In contrast a nerve graft which is large in diameter such as the median or sciatic would not be nourished by surrounding lymph except in a thin peripheral zone and its central portion would undergo necrosis well before its new blood supply would be established. Thus small nerve grafts and cable grafts survive while thick nerve grafts undergo much central necrosis. A nerve graft can hardly be expected to yield as good or as quick a result as a nerve suture because there are in the case of a graft two suture lines each of which forms a cicatricial obstacle through which the axones must penetrate. A nerve suture obviously has only one such line. Even so, however, the speed and degree of regeneration following nerve grafts have compared fairly well with those after nerve suture.

In our series of thirty-two grafts, three were of the cable type and one of the facial nerve was branched into three. The sural nerve was the source of graft in seventeen and other nerves, as in amputation stumps, in thirteen. In two instances a short thin segment from a higher part of the same nerve was split from the nerve and used. The length of grafts used varied from ½ to 6 inches.

CONCLUSION

1. A series of thirty-two autogenous nerve grafts in the human is reported, with return of some function in all and in many to a considerable degree.

2. Experimentally in cats the axones were demonstrated to grow through the

grafted nerve segment and on down through the nerve.

3. Prepared grafts have no advantage over fresh grafts.

4. A nerve graft to be successful should be small in diameter or made as a cable graft of many small strands so that each strand will be nourished through and through by the circulating surrounding lymph until it has acquired its own blood supply.

REFERENCES

1. Albert. Quoted by Davis and Cleveland.[7]
2. Babcock, Wayne. Standard technique for operation of peripheral nerves with especial reference to closure of large gaps. *Surg., Gynec. & Obst.*, 45: 364–378 (Sept.) 1927.
3. Bently, F. H., and Hill. Nerve grafting. *Brit. J. Surg.*, 24: 368–387 (Oct.) 1936.
4. Bunnell, Sterling. Surgery of nerves of the hand. *Surg., Gynec. & Obst.*, 44: 145–152 (Feb.) 1927.
5. Bunnell, Sterling. Surgical repair of the facial nerve. *Arch. Otol.*, 25: 235–259 (March) 1937.
6. Cajal, Ramon. Degeneration and Regeneration of the Nervous System. Translated by R. M. May. Oxford Press, 1928.
7. Davis, L., and Cleveland, D. A. Experimental studies in nerve transplants. *Ann. Surg.*, 99: 271–283 (Feb.) 1934.
8. Duel, A. B. History and development of surgical treatment of facial palsy. *Surg., Gynec. & Obst.*, 560: 384–390 (Feb.) 1933.
9. Dustin. Quoted by Cajal,[6] 1: 335.
10. Forssmann. Quoted by Cajal,[6] 1: 331.
11. Huber, G. C. Transplantation of peripheral nerve. *Arch. Neurol. & Psychiat.*, 2: 466–480, 1919.
12. Huber, G. C. Repair of peripheral nerve injuries. *Surg., Gynec. & Obst.*, 30: 464 (May) 1920.
13. Platt, H. Results of bridging gaps in injured nerve trunks by autogenous fascial tubulization and autogenous nerve grafts. *Brit. J. Surg.*, 7: 384 (Jan.) 1920.
14. Platt, A., and Bristow, W. R. Operation for injuries of peripheral nerves. *Brit. J. Surg.*, 11: 535–567 (Jan.) 1924.
15. Ranson, S. W. Degeneration and regeneration of nerve fibers. *J. Comp. Neurol. & Psych.*, 22: 487, 1912.

NON-OPERATIVE PROCEDURES FOR THE RELIEF OF LUMBO-SCIATICA*

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REFERRED leg pains from lesions of the sacrolumbar spine are everyday problems of the general practitioner. The resulting lumbo-sciatica is too often accepted by the middle aged patient with the resignation accorded false teeth and gray hairs, as the inevitable consequence of mature years. Rest, home remedies and the hot water bag carry the sufferers through their acute attacks. They ignore the constant intermediate chronic ache until eventually they reach the cane supported, limping stage of the semi-invalid. Yet, with proper medical guidance and treatment in the early stages, they could have had many years of comfort before them.

CAUSE

In a previous article[1] I endeavored to show that faulty posture is the usual predisposing cause of chronic lumbo-sciatica; that this faulty posture results in an exaggeration of the dorsal and lumbar curves of the spinal axis. This spinal tilt in the lumbar region puts an added strain and traction on its related ligaments and attached muscles, and finally causes a perineural irritation of the associated nerve roots with pain referred to their distal branches. Flat foot[2,3] and functional muscular insufficiency[4] are the most frequent causes of faulty posture. (Fig. 1.)

The contributory causes are legion, but may be grouped as referred pain arising from pathology in distant parts, or direct pain arising from pathology in the lumbar spine or its surrounding structures. Summarizing possible causes from the 2,182 cases of authors quoted, one concludes (1) "that any contributory cause may be important, but that few per se give symptoms without a superimposed acute trauma or the chronic static trauma of poor posture; (2) that causes of chronic lumbo-sciatica whose frequency is exaggerated are toxic foci, constipation, hemorrhoids, prostatitis, female pelvic disease, especially uterine retroversion and retroflexion, anatomic variations in the fifth lumbar vertebra, sacroiliac strain or dislocation, osteoarthritis of the young (the Marie-Strumpell type excepted), and true lumbar muscle fascitis; and (3) that the true cause is usually found in the spine itself, at or about the lumbosacral articulations, since the senile weakening of its ligamentous and muscular supports throws an extra strain on this vulnerable area and hastens the course of local senile fibrotic changes."[1]

PATHOLOGY

Pain means sensory nerve irritation. When expressed in its terminal branches the irritation is usually about the nerve root. That it is due to a true neuritis is still a much debated question. But the relief following procedures tending to bring more blood into and around the affected nerve; the observation of nerve root changes when exposed by laminectomy;[5,6] and the relief attained by various nerve stretching procedures[1,7,8] indicate that in the majority of chronic cases some degree of peri- and endoneuritis exists.

If "pain is the cry of a suffering nerve for blood," then the pain of *acute sciatica* would follow pelvic nerve root ischemia from perineural pressure of surrounding acutely inflamed structures—periosteum,

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ligaments and muscles. A long continued pressure would result in a low grade chronic inflammation with its attending fibrosis. The fibrosis would first appear in the nerve sheath—perineuritis; then gradually invade the nerve trunk—endoneuritis. Contraction of this newly formed fibrous tissue would cause a persistent nerve ischemia and cause the continuous pain of the *chronic case*. But with the regeneration power characteristic of nerve tissue the neuritis disappears once the primary cause is removed and the secondary nerve changes are treated. Relief attending therapeutic measures and minor surgical procedures tending to bring more blood to the affected nerves would seem to support this hypothesis.

SYMPTOMS

The pain of chronic lumbo-sciatica is transmitted down the leg through the lumbosacral and coccygeal plexuses, particularly along the great sciatic and gluteal nerve distributions. In mild cases there is morning back stiffness and muscle fatigue, followed as the day goes on by pain radiating over the sacroiliac joints, buttocks and down the back of the leg. Sciatica may precede but usually follows the backache. The pain is intermittent. It is aggravated by sudden body twists, lifting, exposure to wet and cold or a toxic focus. The majority of cases are in this class and are those apt to be relieved by minor surgical procedures. The severe, long standing case with constant pain, sensory and motor reflex changes and contraction of fascial planes and muscle groups usually requires a major surgical operation for relief.

TREATMENT

It is nature's law that senile fibrosis with its accompanying pain first appears in those structures most hardly hit by life's wear and tear. In man, the biped, the erector spinal muscle group is in a state of contraction during all his waking hours. It is but logical that this muscle group and its associated nerves, joints and ligaments should be the first to exhibit the pain signal of approaching senile fibrotic change. So the cartoonist depicts the old man not as holding his head with both hands but with

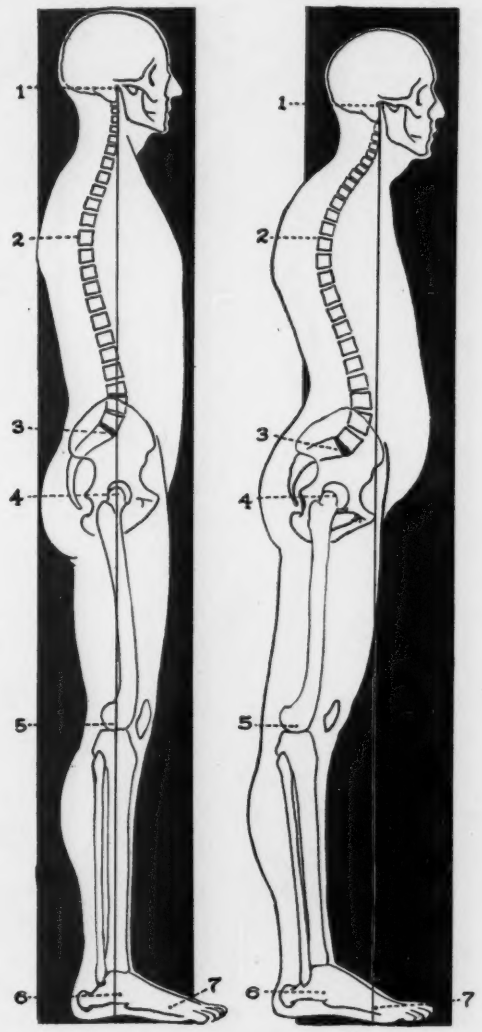

Fig. 1. A, proper posture. A plumb line dropped from the mastoid process (1), passes through the tip of the shoulder, the lumbosacral articulation (3), the hip joint (4), the knee joint (5) and the base of the metatarsals (6). The head is up, shoulders back, dorsal and lumbar curves normal, knees straight and the lumbosacral articulation angle 43 degrees. B, poor posture. The plumb line falls anterior to the lumbosacral junction and strikes the feet about the heads of the metatarsals. General body slump, i.e., head forward, exaggerated dorsal and lumbar curves, protruding abdomen, exaggerated lumbosacral angle, hyperextended knees, feet with a tendency to be flat. (From Steel, in *New England J. Med.* 219: 474, 1938.)

those members supporting a lame back. Correction of predisposing and contributory causes, avoidance of acute trauma and gratifying results that the pessimistic outlook of the past toward chronic lumbago sciatica can be largely changed; the car-

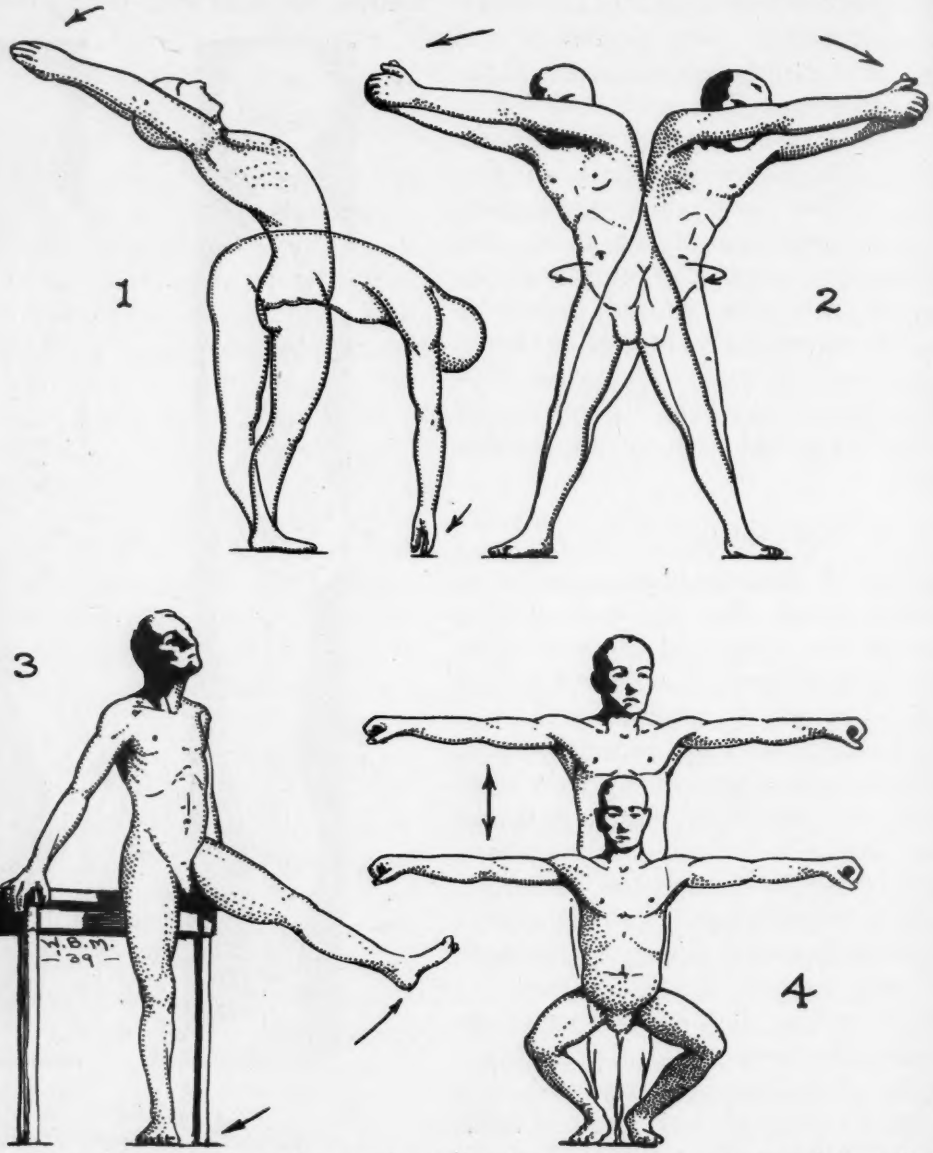

Fig. 2. Type of daily morning active exercises designed to strengthen the erector spinal muscle groups and loosen adhesions of associated ligaments and nerve roots in the lumbosacral region.

methods to bring more blood to and through the secondarily fibrosed area, are the therapeutic principles underlying the treatment of chronic painful neuritis. Surgeons of wide experience[5,10] state that about 10 per cent of chronic sciatica cases require major surgical operations for their cure, while the remaining 90 per cent can be relieved by minor surgical procedures. These measures are now yielding such toonist of the future may replace his doddering, bent old man by an active foxy grandpa.

Chronic lumbo-sciatica is from the standpoint of etiology and treatment a complicated entity. "It is about as logical to refer all backaches to the orthopedic surgeon as it would be to refer all headaches to the neurologist."[11,9] Its cause should be sought for and in most cases its treatment

carried out by that highest type of the general surgeon—an internist trained to operate. Accurate history and a thorough examination—physical, laboratory and *x*-ray—should precede any local treatment. Although the elimination of a local or general toxic condition may not cure the existing pain, it may prevent its recurrence following relief by successful local measures.

PLAN OF TREATMENT

I. Eliminate possible etiologic factors.
   (*a*) Toxic foci or sources of referred pain.
   (*b*) Correct faulty posture.
   (*c*) Correct flat feet.
II. Measures to absorb local fibrosis and free adhesions.
   (*a*) Heat and massage.
   (*b*) Passive motions.
   (*c*) Nerve stretching.
      1. Postural and open methods.
      2. Endoneural sciatic injection.
      3. Epidural intrasacral injection.

Toxic Foci or Referred Pain. Despite the fact that chronic cases in the aged rarely yield to any but local treatment, we are all familiar with the occasional miracle which has followed extraction of an abscessed tooth, desiccation of an infected uterine cervix or insulin therapy in the diabetic. Before beginning local treatment see that any suspicious systemic or distant local focus is put to rights.

Correction of Faulty Posture. Bad posture usually means functional muscular insufficiency. The slumping recruit, as his muscles develop under military drill, soon becomes an erect well postured soldier. Have the patient go through his morning course of spinal and hip flexions, extensions and torsions gradually to strengthen the associated spinal muscles and to loosen ligaments and nerve roots. (Fig. 2.) At night, one hour before retiring, have him take a few strokes on a rowing machine and a hot sitz-bath just before going to bed. Those bending exercises which tend to give pain are the ones to be persisted in. It is a gradual cultivation of the elderly individual

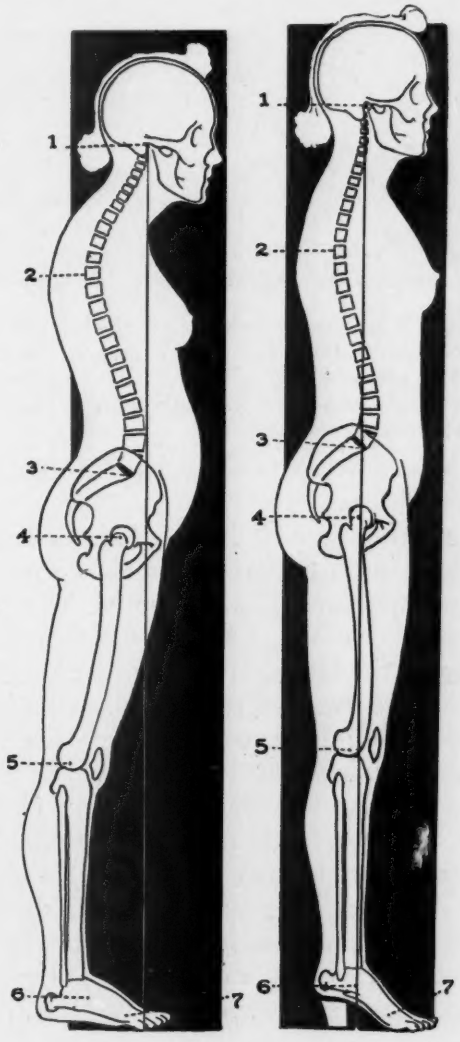

Fig. 3. A, poor posture in a woman: weak musculature, heels flat. B, improved posture by wearing moderately high-heeled shoes with broad walking surfaces. In the slumped figure, if the heels are elevated, the shoulders must go back to preserve a walking balance. (From Steel, in *New England J. Med.*, 219: 474, 1938.)

to resume the gymnasium setting up exercises of his youth. It is perhaps the most difficult part of the whole régime to enforce, for it means a bit of self sacrifice and a little real work in the naturally self-indulgent. But get the patient interested in golf and half the physician's problem is solved. The growth of our country clubs with their large middle aged membership

speaks for itself. Elimination of bed sag tends to lessen the morning back stiffness. Most patients feel best after sleeping on a firm hair mattress held flat by boards across the bed frame.

Fig. 4. Sciatic nerve stretching in the less severe case of sciatica. The patient is anesthetized. The extended leg is rocked back and forth several times until its angle with the table approaches 120 degrees.

Correction of Flat Foot. This is one of the most important points in the correction of faulty posture. The flat footed individual naturally slumps forward. Put a little spring in the feet again by shoes correcting lateral and transverse arch drop and the shoulders tend to go back. Why are high heels popular with women, aside from cosmetic reasons? Because if you elevate your heels your shoulders must go back to preserve a proper balance. (Fig. 3.) Woman, with her weaker musculature, finds that she has less backache and fatigue at the end of the day, when wearing a moderately high heeled shoe with a broad walking surface.*

MEASURES TO ABSORB LOCAL FIBROSIS AND FREE ADHESIONS

Irrespective of the means employed, the principle underlying the treatment of any chronic local inflammatory condition is to bring more blood to and through the part. Practically the whole field of modern physiotherapy is based on this principle. More blood is brought to the affected area by heat and massage, passive motions and nerve stretching. Iodine still holds its place empirically as a fibrous tissue solvent.

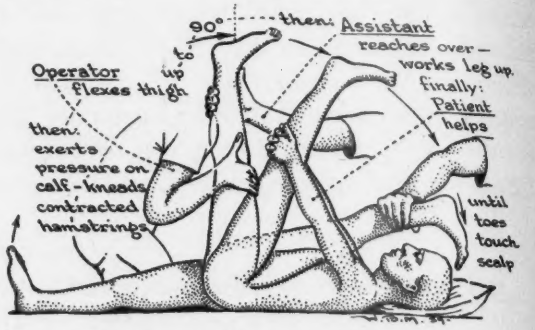

Fig. 5. Baer's complete maneuver of sciatic nerve stretching under spinal anesthesia. By a series of rocking motions carried out by the operator, assistant and patient, the extended leg is brought up until the toes approximate the scalp. Time of maneuver about thirty-five minutes.

Heat and Massage. Early medical records and present habits of primitive races indicate that from prehistoric times heat and massage in some form have been used locally to allay the pains associated with chronic inflammations of muscles, joints and nerves.[11] Heat of any kind—sunshine, hot bath, electric pad, hot lamp, cold lamp of diathermy—holds its place as a means of temporary relief, while the hot flatiron worked over the family ironing blanket still has its rural adherents.

Passive Motions. Those motions directed toward breaking up a partial false ankylosis of the spinal segments, or in freeing adhesions of the spinal nerves in the intervertebral foramina have been largely responsible for the success of the manipulative cults in their relief of back and sciatic nerve pain. They should be used with caution in cases of advanced vertebral lipping and are contraindicated where *x*-ray shows any degree of fracture dislocation, a suspicion of tubercular or malignant disease of the spine, or disc herniation.

Bankhart[8] gives four manipulations carried out under full ether anesthesia. His technique is as follows:

* Fifty women between the ages of 35 and 55 years were questioned by us as to the type of shoes worn during their daily work. All wore some type of lateral arch support, sixteen a metatarsal pad. Forty-six wore a heel more than 1 inch high. The average heel height was 1¾ inches. Average heel width on the walking surface was 1⅝ inches. Forty women (80 per cent) stated that wearing sneakers or shoes with low heels for any length of time caused discomfort or pain in the feet, calves, back of thighs and lower back. Three had foot pain only; two had foot and calf pain; five had foot and thigh pain; thirty had pains in the calf, thigh and lower back. Young women generally seemed indifferent to heel type and wore with comfort whatever the occasion demanded.

1. Sciatic Nerve-Stretching. The patient lies on his back. An assistant steadies the pelvis. The operator holds the leg on his shoulder and keeps the knee stiff with one hand while the straight leg is forced up to the limit of thigh flexion and is rocked back and forth several times. (Fig. 4.)

2. Spinal Flexion. The patient lies on his back. The operator puts an arm under both knees and brings them up to the patient's head.

3. Spinal Rotation. The patient lies on his back. An assistant holds down the right pelvis while the operator standing on the left side, reaches over and forcibly pulls the right arm toward him. The procedure is repeated on the opposite side. Adhesions are often heard to crack during the manipulation.

4. Spinal Hyperextension. The patient lies on his face. The operator puts one arm under the thighs above the knees and forcibly lifts

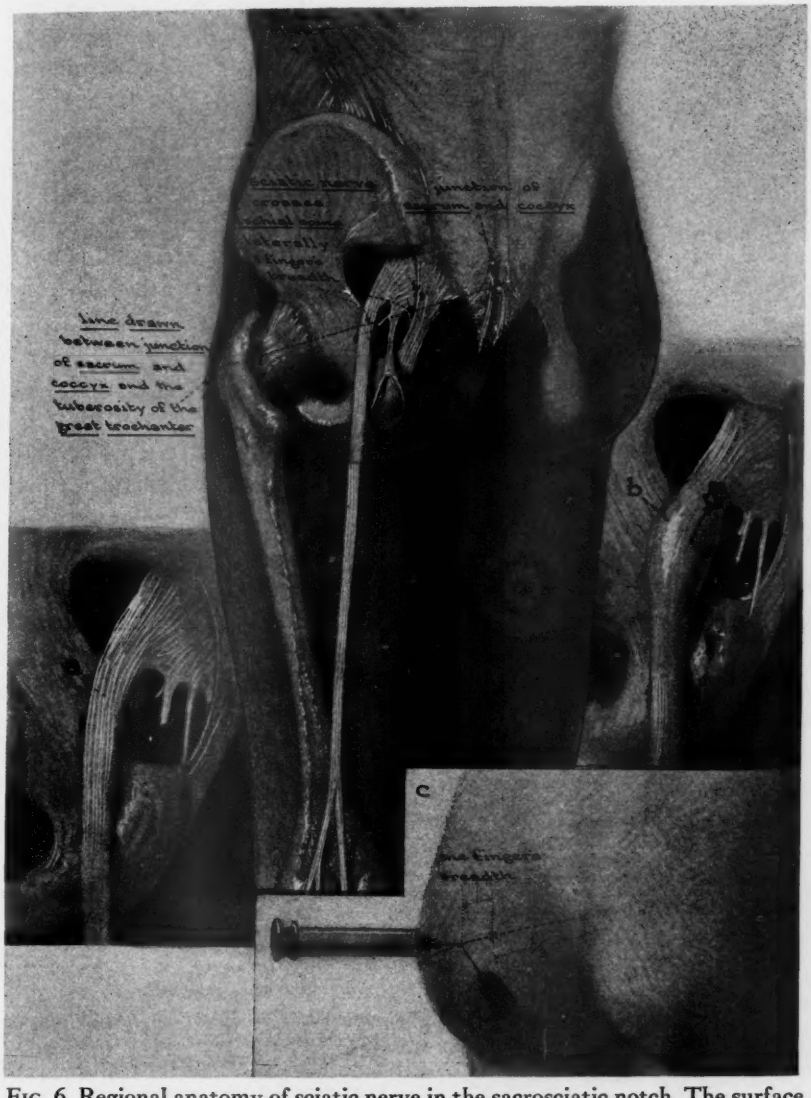

Fig. 6. Regional anatomy of sciatic nerve in the sacrosciatic notch. The surface landmark is a point one fingerbreadth to the lateral side of the medial third of a line drawn from the sacrococcygeal junction to the lower point of the great tuberosity of the femur. The deep landmark is the spine of the ischium. A, size and position of the sciatic nerve as it lies on the spine of the ischium. B, fusiform swelling of the nerve; twice normal size following the intraneural injection of 2 c.c. of fluid. C, needle plunged vertically into the soft tissues at the surface landmark. (From Steel, in *New England J. Med.*, 219: 474, 1938.)

the thighs, holding the back down with the free hand.

Baer's[12] complete maneuver of sciatic

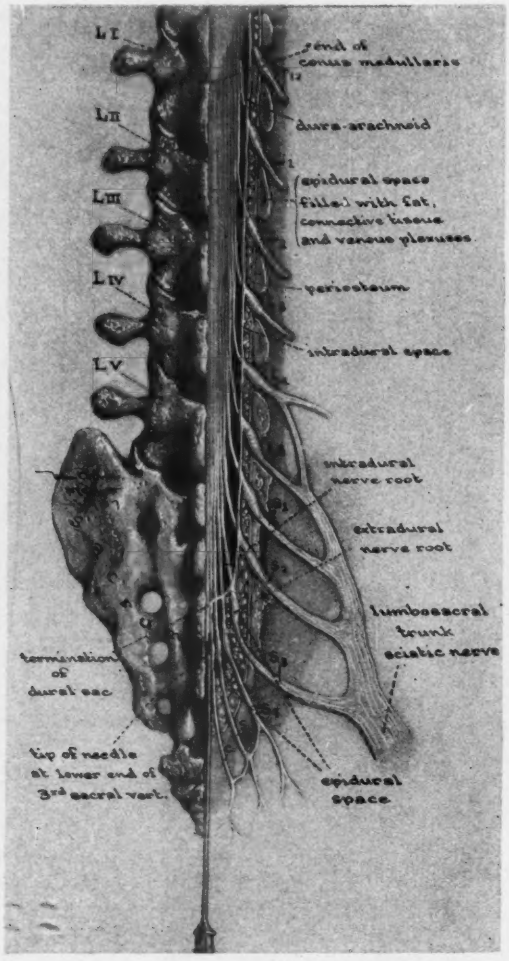

FIG. 7. Anatomy of epidural space: antero-posterior view. The space is filled with fat separating the dura from the intraspinal periosteum for the length of the spinal canal. The epidural space at the second, third and fourth sacral segments is of large size. The spinal nerves run in this space for a distance of 2.5 to 3 cm. from the point where they pierce the dura until they enter the intervertebral foramina. The needle piercing the dense sacro-coccygeal ligament for a distance of 4 cm. is well below the dural sac. (From Steel, in *New England J. Med.*, 219: 474, 1938.)

nerve stretching is carried out under spinal anesthesia as follows:

The operator stands at the foot of the table and by a series of rocking motions brings the extended leg up to 90 degrees. An assistant at the head of the table then reaches down and helps pull the leg up toward the patient's head. The patient finally reaches down and helps pull on his foot until the toes approximate the scalp. There is a tearing sound of the hamstring fascial planes at about 120 degrees following which the leg gives rapidly. The full maneuver takes about thirty-five minutes. (Fig. 5.) A bilateral plaster cast from the costal margin to above the knees is worn for two weeks. In extreme cases a two stage manipulation is done at seven day intervals. Pain relief is usually immediate. Ecchymosis over the hamstring muscles and a transient or persistant paresthesia along the peripheral distribution of the sciatic nerve may follow.

In the less severe office type of case we have found evipal intravenous anesthesia satisfactory for a full course of manipulations, while inhalation of ethyl chloride, preceded by a sciatic endoneural novocaine injection is sufficient for nerve stretching. Severe cases are hospitalized and manipulated under spinal anesthesia. Baer's complete maneuver not only gives a complete nerve stretching but would seem to carry out all that is accomplished by the open fasciotomy operation. With the exception of sciatic nerve stretching daily active motions carried out by the patient seem clinically to give more lasting results than do passive motions.

Direct Nerve Stretching. The postural method has been described under passive motion. Some forty years ago exposure and stretching of the sciatic nerve in the upper thigh was a popular procedure. Enough traction was used to lift the leg clear of the table. The measure gave relief in many cases of intractable sciatica. Attempts to obtain pain relief by direct stretching of other large nerve trunks of the upper and lower extremity usually resulted in failure. Since it has been shown that it is not the peripheral stretch, but the loosening of adhesions about the sciatic spinal roots in the intervertebral foramina that brings relief, one understands why the open method has been largely abandoned.

"*Intraneural Injection.*[1] This is the injection of fluid into the nerve sheath by

skin puncture without exposing the nerve trunk by incision. The sciatic, because of its large size and accurate localization, one finger's breadth lateral to the medial third of a line, drawn across the buttocks, from the sacrococcygeal junction to the

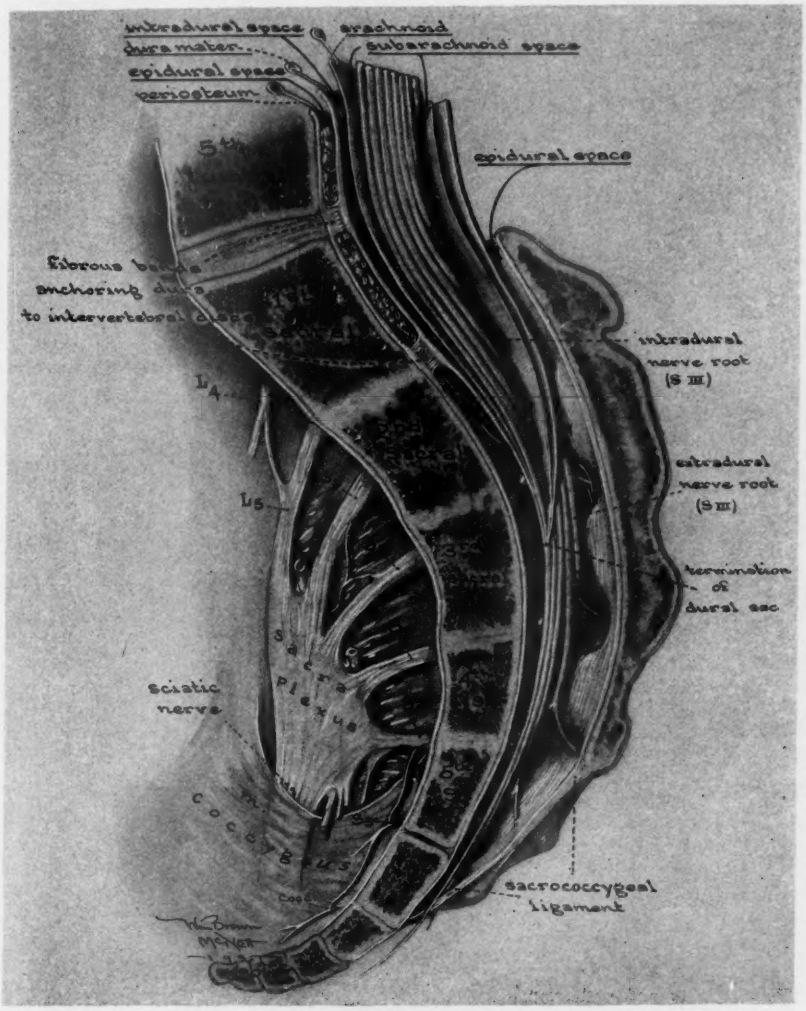

Fig. 8. Anatomy of epidural space: sagittal section. The anterior spinal roots enter the intervertebral foramina and emerge into the pelvis to form the sacral plexus. Fibrous bands anchor the dura anteriorly to the intervertebral discs. The dura is free posteriorly and laterally. (From Steel, in *New England J. Med.*, 219: 474, 1938.)

can be successfully injected. Intraneural injection results in a localized, fusiform swelling which stretches the surrounding nerve sheath and tends to separate the individual nerve bundles inside it. In experiments conducted by us it was found that injection of the sciatic nerve on the cadaver brought out the following points. In the sacrosciatic foramen the nerve rests on the spine of the ischium at an average depth from the skin of 2 inches (5 cm.). The skin puncture guide is a point inferior tip of the great trochanter. The nerve is lifted off the spine of the ischium for ⅛ inch (0.5 cm.). by the gemelli muscles. The nerve trunk is ¾ inch (2 cm.) in lateral diameter and ⅜ inch (1 cm.) in anteroposterior diameter. Two c.c. of fluid quickly injected into the nerve sheath causes a fusiform swelling about twice the size of the normal nerve. Excess fluid over 2 c.c. quickly leaked out through the needle puncture holes into the surrounding tissues. (Fig. 6.)

"*Technique.* The patient lies on the abdomen. The skin surface guide is found, wiped with iodine and alcohol and anesthetized with ethyl chloride spray. A 20 gauge spinal needle 3 inches long is plunged in vertically, and strikes bone—the spine of the ischium—at an average depth of 2 inches (5 cm.). Pain usually shoots down the back of the leg as the needle pierces the sciatic nerve. The needle is withdrawn ¼ inch (0.7 cm.) to insure its point lying inside the nerve sheath. Then 2 c.c. of 1 per cent novocaine in saline is forcibly injected twice at one

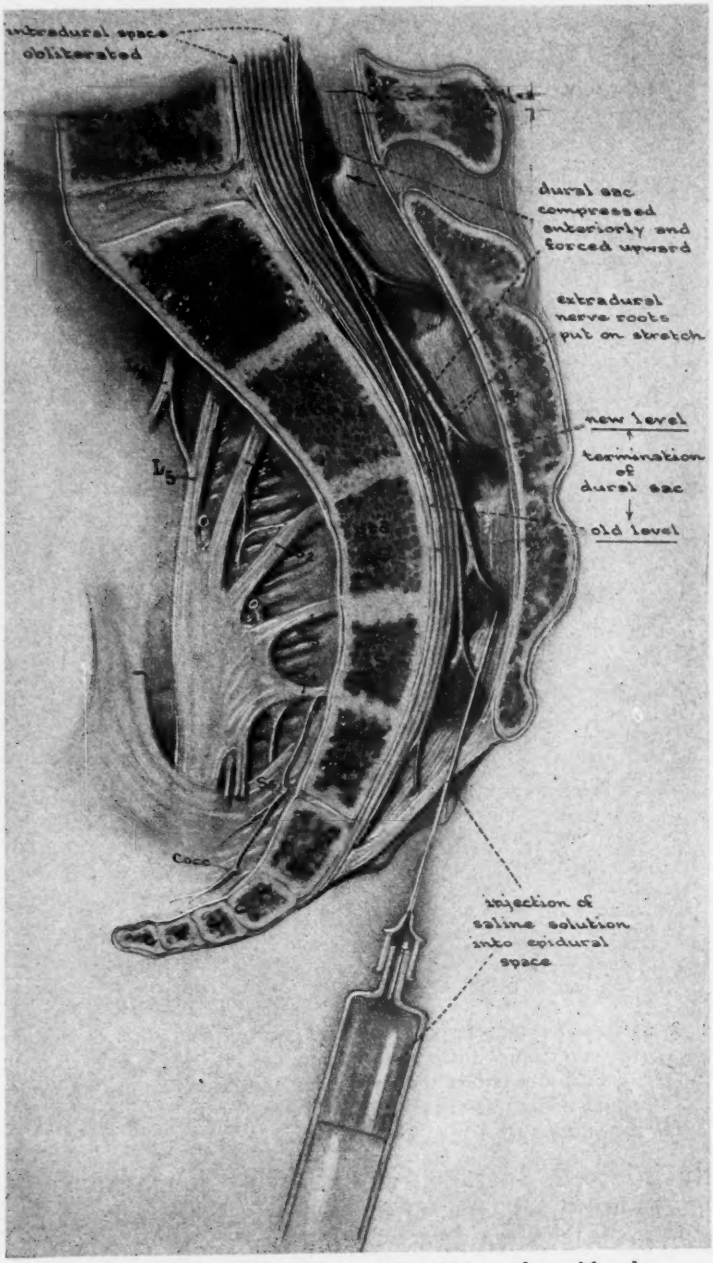
extradural space obliterated
dural sac compressed anteriorly and forced upward
extradural nerve roots put on stretch
new level
termination of dural sac
old level
injection of saline solution into epidural space

Fig. 9. Effect of injection of 30 c.c. of fluid into the epidural space. The sacral nerves and whole spinal dural sheath are compressed anteriorly and the dural sac is forced upward for 2.5 mm. This results in an intraspinal stretching of the nerve roots and tends to free adhesions in the intervertebral foramina. (From Steel, in *New England J. Med.*, 219: 474, 1938.)

minute intervals. Pain shooting down the back of the leg at the time of injection is clinical evidence that the needle point lies inside the nerve sheath. Failure will result if the injection is given extraneurally or in cases of high nerve bifurcation. It is our practice first to inject the nerve; wait a few minutes, until the patient assures us that all sciatic pain has disappeared; then do a postural nerve stretching under ethyl chloride inhalation anesthesia. The patient is sent home to bed for twenty-four hours and local heat applied to the injection site. Results in twenty-five cases gave: complete relief in fourteen, partial relief in six; failure in five. Injection should never be employed in acute, fulminating sciatica.

TABLE I

RESULTS OF EPIDURAL INJECTION IN 75 CASES

Pain Location	Cause	Number Cases	Cure or Marked Relief	Failure
Buttock and sacroiliac region	Idiopathic	18	18	0
Sciatic nerve	Idiopathic	22	14	8
Coccyx	Traumatic	15	15	0
Lower dorsal and upper lumbar	Idiopathic	5	3	2
Malignant low back pain	Cancer prostate	2	0	Relief 7 to 10 days
Malignant low back pain	Uterine cancer	1	0	Relief 7 days
Malignant low back pain metastatic	Cancer of breast	2	Relief—5 months Relief—10 days	2
T.B. low back pain	Mid-dorsal involvment	1	1 (followed by brace)	
Amputation stump through or below knee.	Endarteritis obliterans (Buerger's)	7	0	7
Nocturnal priapism	.....	2	0	2

"*Epidural Sacral Injection.* It has long been recognized that an epidural injection of 30 to 60 c.c. of a 1 per cent novocaine solution into the sacral canal to produce sacral anesthesia, is often followed by permanent relief of a chronic low backache or sciatica. Various authors advocated this procedure for pain relief. But the research work of Evans[7] of the London Hospital, in 1930, gave us our first true understanding of the rationale of the procedure. He showed that when 30 c.c. of fluid was injected epidurally in the cadaver a true nerve root stretching resulted. To appreciate his findings, let us look at the anatomy of the spinal sheath and its nerve offshoots in the lower lumbar and sacral spine.

"*Anatomy.* The spinal cord proper ends as the conus medularis at the first lumbar vertebra. The dural sac continues down to the lower border of the second sacral vertebra. The sac contains cerebrospinal fluid and the cauda equina, i.e., the lumbar and sacral nerve roots. Between the dural sac and the periosteum is the epidural space filled with semifluid fat. The dura is held ventrally by fine fibrous bands, which anchor it to the intervertebral discs. No bands bind it laterally or posteriorly. The space is prominent posteriorly at the second, third and fourth sacral segments. The space is prolonged upward in the spinal canal to the cervical region. The nerve roots run in this space for a distance of 1 to 1½ inches, from the point where they pierce the dura, until they enter the sacral foramina. The nerve roots carry a sleeve of dura out into the intervertebral foraminae. (Figs. 7 and 8.)"[1]

Evans' work on the cadaver and living subject brought out the following facts when fluid is injected into the epidural space:

1. That 30 c.c. of fluid filled the sacral space. When 100 c.c. of colored fluid was

injected it could be traced up into the cervical region.

2. That the fluid filled the space posteriorly and laterally and worked out into the intervertebral foraminae between the dural sleeve and the periosteum.

3. That it forced the whole dural sac upward 3 mm. or 1/10 inch. (Fig. 8.)

4. That the slow intermittent injection of 100 c.c. of fluid gives a slowly repeated nerve stretching and tends to separate adhesions of the nerve in the intervertebral foraminae.

5. That in the living subject there was a rise in spinal pressure from 16 to 30 mm. registered on a manometer through a needle introduced into the fourth lumbar interspace, as the whole spinal sheath was forced upward and compressed.

That is, a true intraspinal nerve stretching follows intradural injection. Our experiments on the cadaver coincided with Dr. Evans' findings.

"*Technique.* The patient lies prone on the table with a narrow hard pillow under the suprapubic region. Feel for the sacral cornua. The hiatus, covered by the dense sacrococcygeal ligament, lies between the cornua and approximately 2 inches (5 cm.) from the tip of the coccyx. The skin is wiped with iodine and alcohol and anesthetized through a fine needle with 1 per cent novocaine. This needle is pushed down and through the sacrococcygeal ligament. A 20 gauge 3 inch long spinal needle is then pushed almost vertically through the ligament until it strikes bone, where it is slightly withdrawn. The butt is depressed and it is pushed up into the canal for 1½ inches (3 cm.). The plunger of the empty syringe is pulled out and if blood or cerebrospinal fluid appears, the needle is withdrawn until nothing appears on aspiration. Then slowly 0.5 per cent novocaine in saline is injected. The fluid should flow freely; if there is obstruction to the piston the needle point is probably imbedded in the periosteum. Withdraw it slightly and inject the fluid slowly and intermittently up to the point of referred pain. One hundred c.c. of solution are used. Pain running out along the course of the affected nerve is a favorable sign. Swelling over the dorsum of the sacrum is evidence that the needle is outside the sacral canal. The patient rests on the table for one-half hour and is then sent home to bed for twenty-four hours, local heat being applied over the injection site for twenty-four hours. Local heat, exercises and indicated general systemic treatment, are insisted on following all minor surgical procedures. Table 1 gives results in seventy-five epidural injections given during the past 4 years."[1]

In 178 reported cases of sciatica,[13,14] including twenty-two of our own, cure or marked relief resulted in 70 per cent plus. It is worthy of note that in our seventy-five epidural injections complete back pain relief occurred in all of the coccygodynia type and in the sacroiliac type with pain radiating down over the buttocks. It is our feeling that epidural injection, endoneural injection and postural nerve stretching offer more hope of relief in those with chronic low back pain and sciatica, who have been for months or years through the usual therapeutic mill, than any other known medical or minor surgical treatment. These procedures fail in cases of referred pain.

CONCLUSIONS

The cause of chronic lumbo-sciatica is usually found at or about the lumbosacral articulation as a progressive fibrosis of its related ligaments and muscles and its associated nerve roots. The condition is aggravated by acute trauma, the chronic static trauma of poor posture, local toxic foci or systemic toxemias.

The first requisites of treatment are an accurate history and a thorough physical, laboratory and *x*-ray examination. Any toxic focus or source of referred pain should be eliminated. Faulty posture should be corrected by progressive, active motions and proper shoes; golf is recommended for the middle aged man, and moderately high

heeled shoes for the middle aged woman. Active motion with discretion is more important than the indiscriminate rest usually prescribed.

If pain persists, use in the following order:

For sciatica: endoneural injection, postural nerve stretching, epidural endosacral injection. For low backache: epidural endosacral injection and perhaps spinal manipulation. If pain still persists, some major surgical procedure by a skilled operator must be considered.

Systemic regulation, heat, massage, proper shoes and regulated exercise are essential following any minor surgical procedures. If one is looking for any specific that will cure all types of lumbosciatica or any one of them, disappointment is certain.

REFERENCES

1. Steel, W. A. Relief of chronic backache and sciatica by minor surgical measures. *New England J. Med.*, 219: 474–483 (Sept. 29) 1938.
2. Stamin, T. T. Role of manipulation in the treatment of lower back pain. *Guy's Hosp. Rep.*, 84: 372–382, 1934.
3. Moore, J. R. Address before the Vermont State Med. Soc., Oct. 4, 1937 (Unpublished).
4. Hauser, E. D. W. Low back pain. A new explanation of its pathogenesis and treatment. *Surg., Gynec. & Obst.*, 57: 380–383, 1933.
5. Kimberley, H. G. Low back pain and sciatica: its etiology, diagnosis and treatment. *Surg., Gynec. & Obst.*, 65: 195–216, 1937.
6. Fay, T. Personal communication.
7. Evans, W. Intrasacral epidural injection in the treatment of sciatica. *Lancet*, 2: 1225–1229, 1930.
8. Bankhart, B. Manipulative Surgery. London, 1932. Constable. Quoted by Wallace, S. A. Lumbago and sciatica. *Canad. M. A. J.*, 34: 174–177, 1936.
9. Hartung, E. F. Low back pain. *New York State J. Med.*, 36: 979–982, 1936.
10. Compere, E. L. Operative treatment for low backache. *J. Bone & Joint Surg.*, 19: 749–758, 1937.
11. Pemberton, R. Practice and Principles of Physical Therapy. First revision. Vol. 1, Chap. 7. Hagerstown, 1936. W. F. Prior Co.
12. Baer, W. S. Sacro-iliac strain. *Johns Hopkins Hosp. Bull.*, 27: 159, 1917.
13. Sarbatorescue. The treatment of sciatica by local anesthesia. *Bucharest M. J.*, 1936.
14. Craig, W. M., and Ghormley, R. K. Significance and treatment of sciatic pain. *J. A. M. A.*, 100: 1143–1148, 1933.

FRACTURES ABOUT THE ELBOW

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IN fractures of bones about the elbow the end result is very largely determined by the character of the treatment employed. Some of the most unfortunate sequelae are mute testimony to the ignorance or indifference of the surgeon responsible. Poor results are often seen in these cases despite the fact that many are in children in whom ordinarily nature is a kindly and often miraculous restorer. After an injury to the elbow the restoration of normal function requires the preservation of the contours and relationships of its several articulating surfaces. It depends also upon the amount and permanence of damage to the periarticular soft tissues and is profoundly influenced by some of the complications, as for example, ischemic contracture or ossifying hematoma which occur particularly in this region.

Of course, the surgeon cannot control the degree of original trauma and displacement, but he may exercise an influence over the reduction of bony displacements, the avoidance of secondary trauma, the early and complete resolution of exudation and hemorrhage, and the restoration of movement without impediments due to periarticular adhesions or muscle atrophy. If careful attention be given to these details the results in fractures of this region can be as satisfactory as those in any other part of the body.

This paper is not intended as a detailed analysis of the fractures occurring about the elbow. We shall present few statistics and no detailed reports. The experience of the senior author has been reported elsewhere in detail and the reader who is interested is referred to several previous reviews which are cited among the references. The man who does a great deal of fracture work will find nothing new or startling herein, but for the one who treats fractures only occasionally and wishes to avoid complications and disappointments, we shall strive to emphasize the main practical considerations bearing upon the management of these fractures.

ANATOMIC CONSIDERATIONS

The elbow is a complicated mechanism, providing an obvious hinge motion in which all three bones participate, and also allowing rotation of the forearm by means of the radiohumeral articulation. In so far as flexion and extension are concerned, it must be borne in mind that the arcs which form the articulating surfaces of the condyles are normally placed somewhat in advance of the humeral shaft due to a forward angulation of about 45 degrees at the lower end of the bone. If the relationship of these articular surfaces to the shaft and to each other is to be correctly interpreted from *x*-ray films, true lateral views must be obtained.

The trochlea projects somewhat more distally than does the capitellum, accounting for the normal valgus inclination known as the carrying angle. The maintenance of this angle is a clinical point of importance.

Several of the bony prominences are easily palpated and the presence of local tenderness or any disturbance in normal relationships is exceedingly helpful in diagnosis. The epicondyles are important landmarks, the internal one being the more prominent. The tip of the olecranon can be felt even in the presence of swelling. It and the two epicondyles lie upon the same horizontal level with the elbow extended and the lines connecting the three

form an equilateral triangle when the joint is in right angle flexion. It is also helpful to remember that the external epicondyle lies in the same vertical plane as the greater tuberosity. The head of the radius may be palpated on the extensor or posterolateral aspect and may be rotated under the finger by supinating and pronating the hand. The depressions represented by the coronoid and olecranon fossae of the humerus normally accommodate the respective processes of the ulna in extremes of flexion and extension. Any alteration within these hollows inevitably limits these movements.

Although the osseous relationships are important certain soft tissue structures deserve equal consideration especially since they cannot be visualized on an *x*-ray film. The synovial membrane of the joint will be torn in those fractures which enter the joint, and may be severely contused by any injury in this region. Joint effusion is thus an early complication and chronic synovitis a late sequel. The envelopment of the head of the radius by the orbicular ligament has familiar implications. The insertions of the triceps, biceps and brachialis anticus into the radius and ulna as well as the origins of the flexor and extensor groups from the supracondylar ridges all have a bearing on reduction and upon the position chosen for maintenance. The cubital space, a closed compartment between the anterior capsule of the joint and the lacertus fibrosus or expansion of the biceps tendon, contains the brachial vessels or their branches, the radial and ulnar, as well as the median nerve. The possible effects of tension or compression of this compartment are matters of movement. The ulnar nerve, winding about the internal condyle on its course to the forearm, may be traumatized at the time of injury or become involved in callus later.

SUPRACONDYLAR FRACTURES

This is the most commonly encountered fracture in the elbow region and 84 per cent of our cases have been in children under 10 years of age. The usual supracondylar fracture occurs at the point where the bone takes a forward inclination at a level which is further weakened by the thinness of the bony septum between the coronoid and olecranon fossae. A variation sometimes observed is a fracture line at a slightly lower level passing transversely through rather than just above the condyles.

Since the findings and management of both diacondylar and supracondylar fractures are essentially the same, they will be considered together. Usually the injury results from a fall upon the outstretched hand with the elbow extended. The line of fracture is oblique, running from the anterior surface of the bone upward and backward. Displacement of the lower (condylar) fragment is correspondingly up and back and sometimes laterally as well. Infrequent cases are seen, more often in adults rather than children, in which a reverse displacement is encountered. Only about 6 per cent of supracondylar fractures are of this "flexion type" and this small group will, of course, require management different from the others.

The deformity usually is quite obvious although its details may be obliterated by soft tissue swelling which rapidly reaches striking proportions. The arm is actually shortened and the forearm appears to be. There is a conspicuous abnormal curve of the posterior aspect of the arm. The three bony prominences formed by the epicondyles and the olecranon can be felt in their normal relationship to one another which excludes a posterior dislocation of the elbow. The lower end of the upper fragment can be palpated as a fulness beneath the biceps tendon. Abnormal mobility at the fracture site can usually be demonstrated although its elicitation, like that of crepitus, may cause so much pain that it is not justifiable.

The presence of swelling must never be used as an excuse for delaying reduction since a gentle manipulative procedure is

the best means of reducing the fracture. It is better, of course, to obtain reduction before swelling occurs and hence every fresh supracondylar fracture should have emergency treatment. General anesthesia is essential since the tension already present in the soft tissues precludes the use of local infiltration, and brachial plexus block is hardly practicable in patients of the age usually encountered. The fluoroscope, although not indispensable, is of great assistance and saves much valuable time in securing satisfactory position. The lack of facilities for taking an *x*-ray should not cause delay.

Reduction is done by grasping the forearm with the elbow flexed at right angles while an assistant makes countertraction on the upper part of the arm. The fragments are first freed by hyperextension and then approximated by making traction upon the forearm and pressure backward upon the upper fragment. The next step is to determine the position required to maintain reduction. Hyperflexion is usually necessary since in this position the coronoid is wedged into the coronoid fossa anteriorly while the triceps tendon and fascia form a hammock-like support posteriorly. However, even with hyperflexion, the condylar fragments will sometimes rotate independently of the shaft when the forearm is brought across the chest for the purpose of employing a sling. In this event the lateral hyperflexed position must be used, the hand being approximated to the shoulder of the same side, the forearm and arm thus being maintained in the same sagittal plane.

COMPLICATIONS

Volkmann's ischemic contraction is a complication especially to be dreaded. This crippling paralysis and contracture results from interference with the circulation and nerve damage due to intrinsic tension or external pressure about a swollen elbow. It is seen most often in association with supracondylar fractures because of the accumulating hematoma beneath the anterior fascia and because, unless the fragments are reduced, the hyperflexed position results in compression of the brachial artery and vein between the lower end of the upper fragment and the coronoid.

The damage may occur within a few hours and is irremediable. It does not take place without warning and can be prevented if the signs are recognized in time. A dusky cyanotic forearm suggests venous obstruction while a pallid cold hand with absent radial pulse suggests the still more serious arterial occlusion. Pain is usually severe and persistent but may be transient, disappearing as necrosis of tissues develops.

There are some supracondylar fractures in which the radial pulse is absent when the patient is first seen. Prompt reduction is called for and in most instances the pulse then returns. If it does not and color changes develop, serious consideration should be given to the operation of fasciotomy to relieve tension about the elbow. In other cases the pulse is present before and immediately after reduction but disappears when the elbow is hyperflexed. In this event the patient should be dressed in the degree of flexion which provides good radial pulsation. Every patient whose elbow is placed in the hyperflexed position must be carefully observed during the succeeding twenty-four hours. Should the pulse disappear, the forearm must be brought down to a right angle position or fully extended and elevated on a pillow. This may mean loss of the reduction, but whereas a fracture may always be reduced a second time, a Volkmann's contracture is a permanent disability.

Ossifying Hematoma. The hematoma at the site of a fracture ordinarily resolves without causing any inconvenience to the patient. About the elbow and particularly in supracondylar fractures the usual healing process may be disturbed by the deposition of calcium in the hematoma. This may be due to the stripping of periosteum which often occurs in these fractures. Undoubtedly there is another factor over which the surgeon may exer-

cise control, namely the injudicious use of heavy massage and passive motion during convalescence. These ill advised physiotherapeutic measures serve to disturb and irritate the normal reparative process. Furthermore, when functional progress seems to be at a standstill and *x*-ray reveals an ossifying hematoma, the best therapeutic course is the conservative one of rest rather than operative intervention which tends only to aggravate the condition.

Distortion of the carrying angle with either cubitus valgus or cubitus varus is a permanent and disfiguring if not actually incapacitating deformity. It indicates an imperfect reduction of a supracondylar or condylar fracture. It can and should be avoided.

Treatment after Reduction. Whatever method of immobilization is adopted attention must be given to the restoration of elbow function as soon as the danger of displacement of fragments has passed. At the end of ten days, on an average, gentle guided active motion may begin within pain limits. The patient is encouraged to move the arm once or twice and the dressing is reapplied. It is sometimes difficult to gain the confidence of children so that they actively coöperate in this, but any manipulation which causes pain will most certainly delay the child's normal recovery. Normal function should be regained after supracondylar fracture since it is not a joint fracture and the factors which may impair the ultimate result are well within the surgeon's control. The most important of these are accurate early reduction, suitable maintenance and attention to the restoration of motion maintaining complete power of flexion even at the expense of extension if necessary.

FRACTURES OF THE EPICONDYLES

These are uncommon, the greatest clinical importance attaching to those fractures of the medial epicondyle which complicate dislocation of the elbow. In these the small humeral fragment may be displaced into the joint cavity where it is an obstacle to reduction of the dislocation and may necessitate arthrotomy. The ulnar nerve may be

Fig. 1. Senior author's plaster dressing for the lateral hyperflexed position. (From Eliason's "Fractures of the Humerus, Radius and Ulna," D. Appleton-Century Co.)

displaced with the fragment. Uncomplicated fractures of either the medial or the lateral epicondyle may be regarded as sprain fractures of no great moment. Diagnosis is made by palpation for local tenderness and deformity. Joint motion is not affected in fractures of the medial epicondyle although it may be in those uncommon cases involving the lateral epicondyle since the latter lies within the capsule of the elbow joint. The treatment is ordinarily that of a soft tissue trauma. The epiphysis of the internal epicondyle does not unite with the rest of the bone until a rather late age and caution must be exercised in the interpretation of *x*-ray films lest a normal epiphyseal line be mistaken for a fracture.

FRACTURES OF THE CONDYLES

Ranking third in frequency among the fractures about the elbow, these are of particular interest because all of them are articular fractures, many involve growing epiphyseal regions and a certain number represent a single constituent of multiple and complicated bony injury to the elbow region.

The epiphyseal injuries present especial difficulty from the diagnostic standpoint. The interpretation of *x*-ray films is full of pitfalls but many of these may be avoided by making comparisons with the elbow of a normal child of the same age or, better still, comparing with the uninjured elbow of the patient.

The centers of ossification appear first for the capitellum and a portion of the trochlea during the second year. At the age of five the internal epicondyle becomes apparent. At ten the remainder of the trochlea is evident. Finally at thirteen the center for the external epicondyle may be seen and this soon unites with the centers for the capitellum and trochlea to form a common epiphysis which in turn will unite with the shaft during the seventeenth year. Thus for a brief period between the ages of 13 and 17, the three may separate as a group, leaving the internal epicondyle which unites last of all at about the nineteenth year or later.

When separation of any of these epiphyses occurs, there will be physical signs of injury at the elbow with limitation of motion but little deformity, since displacement is usually slight. True lateral *x*-ray films are helpful in showing a disturbed relationship of the normal forward curve of the lower extremity of the humerus. Accurate reduction should be the aim, but this does not absolutely insure against growth disturbance which may occur regardless of the accuracy of the reduction and, indeed, even though gross displacement is not present.

The prognosis should be guarded since it cannot be predicted with certainty whether the result may be retarded, excessive or normal growth. Fortunately, after the age of ten most of the growth of the humerus occurs at the upper end. In cases with considerable displacement in which closed reduction is unsuccessful, the surgeon, albeit with reluctance, must face the necessity for open operation. The best results appear to have followed simple replacement without the introduction of foreign agents as a means of internal fixation.

A second group of fractures consists of those of the individual condyles occurring after the epiphyseal age. The external condyle is the one more commonly involved since it may be sheared off by indirect trauma, as from a fall on the hand with the arm abducted, as well as being more exposed to direct trauma. The external condyle lies almost wholly within the joint cavity, and lacking the muscular attachments which tend to retain its mesial counterpart, fragments from it may be considerably displaced. There may be rotation of these fragments. This defies reduction by closed methods and is a serious impediment to joint function unless the fragments are accurately replaced by operative means. In both condyles exact restoration of the normal articular contours is extremely important. Marked disturbance of the normal carrying angle as well as limitation of motion may follow inaccurate reduction. The majority of these fractures show no more than a slight displacement, which is indeed fortunate, for reduction is by no means easy. The diagnosis of these fractures may be inferred from the local tenderness and interference with elbow motion, but *x*-rays are essential to accurate diagnosis and proper treatment.

The third type of fracture in this region is that which splits both condyles from the shaft, the fracture lines describing a letter T or Y. These fractures are on the increase as a result of automobile accidents in which the victim has an elbow projecting from the car window at the moment of impact. The elbow is often shapeless, swelling is marked and palpation gives the characteristic sensation of a "bag of bones." Some semblance of normal contour can be obtained by moulding, but displacement is apt to recur as soon as pressure is released. Not infrequently the fracture of the condyles is associated with other fractures below the joint, as for instance, the head of the radius or the

olecranon. In a few instances the situation is further complicated by a compounding of one or more of the fractures. It is practically impossible in many of these cases to maintain proper alignment of the condylar fragments by any of the usual ambulatory methods of splinting and continuous traction is therefore necessary to overcome the tendency of the shaft fragment to split the two condyles and displace them laterally. The prognosis for function in these cases is not favorable under any circumstances. Operative reduction with nail fixation has been advocated, but the results have not been brilliant. Probably as good if not better elbow motion may be regained by early active movement as soon as the fragments have become fixed. This must be conducted with caution under the personal supervision of the surgeon. It is generally felt that children may be expected to regain fairly good function but actually most of the cases are seen in adults. Much of the crippling often seen after these fractures is preventable if the surgeon will take the time and effort required to encourage active motion.

FRACTURES OF THE CAPITELLUM AND TROCHLEA

Fracture of the capitellum is unusual, having an incidence of only about 0.5 per cent in our series of fractures. It may occur either in children or in adults. In the former the displacement is not marked, but shows as a flattening of the forward curve on the articular surface of the bone in the lateral *x*-ray view. It may interfere with joint movement if unrecognized, but growth disturbance need not be expected since the fracture line passes distal to that of the epiphysis. In adults the fragment is usually displaced forward into the joint cavity where it behaves as a foreign body and does not absorb. The signs suggest a fracture of the head of the radius but rotation of the forearm under the examining fingers shows that the radius is intact. *X*-ray examination is essential.

Our experience with reduction by manipulation has not been very successful, but the recent case reported by McLaughlin demonstrates that it can be accomplished with good results. If the fracture line extends beyond the joint confines, reduction either by closed or open methods will usually result in union. If the fragment is completely intra-articular or if closed reduction is unsuccessful, operation must be done and the fragment removed or fixed. After successful closed reduction the extremity should be dressed in the position which best maintains reduction. This frequently is found to be hyperflexion.

Fractures of the trochlea are even more unusual. The diagnosis can only be made with certainty from the *x*-ray film. Operative removal of the fragment should be done if a single attempt at reduction under the fluoroscope is not successful.

FRACTURES OF THE OLECRANON OF THE ULNA

These are common enough to be familiar to all. The line of fracture usually crosses the base of the olecranon process at its junction with the coronoid. Unlike its analogue in the lower extremity, the patella, fractures of the olecranon are rarely comminuted.

The diagnosis is readily made from the examination, which reveals local tenderness, painful limitation of flexion and extension of the elbow and a palpable defect in the bone. Even with extensive effusion into the joint the subcutaneous border of the ulna can be palpated. Since the deformity is one of separation, crepitus may often be absent. About one quarter of the cases of fracture of the olecranon have complicating fractures, more commonly of the head of the radius, the coronoid process or the internal condyle. For this reason two plane *x*-ray films are essential.

The indications for treatment are clear enough. With only slight separation, the elbow is immobilized at right angles and cautious exercise begun after two weeks. Union may be fibrous but satisfactory for

use. When wide separation is present operation and suture give the best result. There may be general contraindications to an operation but efforts to approximate the fragments by means of adhesive straps or bandage are not apt to succeed and the elbow will be weakened. In compound fractures debridement and suture are clearly indicated unless the time elapsed since injury makes operative interference hazardous from the viewpoint of infection. Bone and joint are both exposed at operation and the most rigid aseptic technique is required. The procedure consists of drilling holes through both fragments for the passage of an approximating suture and closing the tear in the triceps aponeurosis.

The material chosen for suture has given rise to considerable controversy. Undoubtedly non-absorbable materials permit more early exercise of the joint but the wisdom of using a wire suture in this subcutaneous location may be questioned even though only occasionally does it cause irritation. Fascia lata is theoretically ideal, but a certain familiarity with its use is required of the surgeon. We have obtained good results with No. 1 chromicized catgut.

After operation the elbow should be fixed at a right angle until acute soreness subsides and then the forearm is carried in a simple sling while motion is being recovered by frequent periods of active movement. The disability period is usually from six to eight weeks. Dressing of the elbow in an extended position is often advocated for these fractures, but has very limited application. Obviously in the absence of separation or after operative fixation, the extended position is not required. In rare cases with moderate separation this dressing may serve to bring about approximation, but the position is awkward and cumbersome to the patient as compared with the use of a sling. Complicating fractures usually make operative suture of the olecranon imperative since only after fixation of the latter can the associated injuries be properly managed.

FRACTURES OF THE CORONOID PROCESS

These are practically never encountered alone, but usually occur as a complication of posterior dislocation of the elbow or less often of fracture of the upper end of the radius, the internal condyle or the olecranon. Such a fracture should be suspected in dislocations which will not remain reduced. Lateral *x*-ray film is necessary for diagnosis. Displacement is limited by the attachments of the brachialis anticus muscle and union is the rule although it may not be osseous. Hemorrhage in the cubital fossa may ossify and this complication must be considered. The right angle position of the elbow is satisfactory for dressing in most cases, but hyperflexion may sometimes be required.

FRACTURES OF THE HEAD OF THE RADIUS

One of the most frequent of the injuries about the elbow, it is usually encountered in adults, but may occur as an epiphyseal fracture between the ages of 7 and 14. The mechanism producing this injury is a fall upon the pronated and extended forearm. The radial head is thus driven against the condyle and crushed, or a portion of its rim is split off. Since the orbicular ligament closely surrounds the radial head, any displacement of a fragment indicates that it has escaped through a tear in the ligament and the improbability of reduction by closed means is obvious.

The diagnosis rests upon pain on supination and tenderness on the back of the forearm just below the lateral epicondyle. A fragment displaced to the ulnar side may not be palpable, but it will interfere with flexion. When there is no displacement, *x*-ray is essential to confirm the suspicion of fracture.

As has been suggested, closed reduction of a fracture of the head of the radius is usually not feasible. The question is whether simply to splint or advise operation. In fractures without displacement the obvious treatment is immobilization with the elbow at a right angle until the soft tissue tenderness subsides, usually a

week to ten days. Then active motion is begun. When the head of the bone is severely crushed or a fragment is clearly separated, operation certainly offers better chances for functional recovery than conservative measures.

In none of these cases should too optimistic a prognosis be given, for traumatic arthritis with painful restricted rotation may follow an apparently minor injury with or without displacement and regardless of treatment. At operation replacement of the fragment is only to be considered in cases of epiphyseal injury. If the fragment be a small one, less than a third of the circumference of the head, simple removal is probably indicated and active motion is begun immediately. If a greater portion of the head is involved not only should all loose fragments be removed but the entire head and neck resected and motion encouraged from the outset. This fracture quite commonly results in a useful elbow but not so often in a normal one.

FRACTURES OF THE NECK OF THE RADIUS

These are significant due to the fact that any alteration in the normal axis of the neck implies a corresponding disturbance in the articulating surface of the head. The interference with normal pronation and supination may therefore be quite as great in fractures of the neck of the radius as it would be if the head itself were directly involved. As a matter of fact fractures of the two frequently coexist, notably in those which have the characteristic "mushrooming" of the upper end of the radius. The clinical signs of the two fractures are very similar. Treatment differs in that one may expect in many cases to correct deformities of the radial neck by manipulation and thereby restore the proper articular relationships. On the other hand, if these cannot be restored, operative resection of head and neck will alone ensure normal function. As previously mentioned the prognosis following this operation should always be reserved.

DRESSINGS FOR FRACTURES ABOUT THE ELBOW

A good reduction is often spoiled by insufficient attention to the choice and maintenance of a suitable dressing. A common error is to assume that all fractures at a given level should be treated in the same way. This is by no means true and supracondylar fractures may be cited as an example. Two cases may present identical initial deformity yet it is found in one that when the forearm is brought across the chest after reduction the condyles undergo rotary displacement. In the other there is no displacement, the fragments remaining locked. The first of these cases must therefore be dressed with forearm and arm in the same anteroposterior plane using plaster of Paris fixation in lieu of the sling which may be quite sufficient in the second instance. Again, in supracondylar fractures deviation must sometimes be made from the usually desirable hyperflexed position, for there are cases in which hyperflexion may displace the fragments or soft tissue swelling may dictate that the elbow be dressed at a right angle rather than in hyperflexion.

The dressing is after all only a means adopted to maintain the reduction, insure comfort to the patient and avoid complications. It should be suited to the individual and not the reverse. Accordingly, in discussing the various fractures of this region, we have refrained from making any dogmatic statements about the style of splint or dressing which may be required. The decision must be made by the surgeon according to the particular requirements presented by the case and often he can make this decision only after he has reduced the fracture and observed its behavior under the fluoroscope.

There are in general four alternative positions in which one of these fractured extremities may be placed while the patient remains ambulatory.

1. The elbow flexed to a right angle and the forearm carried in front of the body

and supported by a sling. In the vast majority of cases it suffices to have the forearm in the midposition as regards rotation but occasionally pronation or supination are required.

2. The elbow hyperflexed so that the hand approaches the shoulder of the same side and the forearm and arm rotated as a unit across the chest. This is the so-called anterior hyperflexed or Jones position.

3. The elbow hyperflexed with the forearm in the plane of the arm without rotation. This is the lateral hyperflexed or Eliason position.

4. The elbow in extension or semiextension.

In certain instances it may appear obvious to the surgeon that none of these ambulatory dressings will be satisfactory and that continuous traction and suspension in bed is necessary. This may be dictated by the inability to retain the fragments except by constant traction, by the excessive swelling of the soft parts, by the presence of a compound wound or by other equally good reasons. A fifth form of dressing has thus to be occasionally considered.

The right angled position and sling suspension may be called for in a variety of fractures with little or no original displacement. It finds common usage with fractures of the head and neck of the radius, the coronoid, the olecranon after open reduction, and in some of those involving the condyles. The position may be maintained in a variety of ways. A simple triangular sling may be sufficient or it may be used in conjunction with an internal right angle or an anterior right angle splint, either of which may be of wood or of plaster reduplications moulded to the part. We make frequent use of moulded plaster splints, but do not look with favor upon the use of circular plaster casts in the treatment of injuries about the elbow. If full pronation or supination of the forearm is required, as it may be in rare instances of fractures of the individual condyles, a well fitted plaster mould will retain the desired degree of rotation far more satisfactorily than any ready made splint of wood or metal.

The anterior hyperflexed position finds its most frequent application in supracondylar fractures but may also be useful in those involving the condyles separately, the capitellum, the trochlea and occasionally the coronoid. It may be the simplest sort of halter which may well be described as a collar and cuff sling in which the wrist is suspended at the level of the suprasternal notch. Uncomfortable pressure may develop at the back of the neck and over the ulna and these parts should be padded. Our custom is to thread the muslin bandage which is used for the sling through two lengths of soft rubber tubing. The patient should be shown that slightly elevating the wrist with the other hand and thus shifting the position of the tube will relieve this pressure. It is surprising how many patients are afraid to do this unless instructed by the surgeon. The skin in the flexion crease may become chafed and should be cleansed and dusted with powder daily.

Many patients or more especially their parents are disturbed because the site of fracture is not covered by this dressing. Actually this is not necessary as the condyles are wedged between the coronoid in front and the triceps expansion behind. An encircling bandage or a compressing splint about the elbow is apt to do more harm than good by interfering with circulation. Usually swelling subsides rapidly after an accurate reduction but blebs may appear and require attention.

Extreme hyperflexion is rarely needed for longer than a week or ten days at the end of which time the wrist is gradually lowered. At each adjustment of the dressing the range of motion within pain limits is gently tested and if complete flexion becomes difficult the forearm is returned to the hyperflexed position for a few days.

The lateral hyperflexed position, as has been noted, is used in those instances in

which rotation dislodges the fragments. We use it in about one out of every three cases of fracture through the supracondylar level or the condyles themselves. Some have advised an encircling strip of adhesive or a bandage about the forearm and arm with the elbow hyperflexed but this is open to the objections mentioned to any encircling bandage about the elbow. Our preference is for an anterior plaster splint moulded carefully about the forearm and arm and reinforced by several turns of plaster which begin in the interscapular region, pass forward over the shoulder, downward on the inner side of the hyperflexed elbow and then swing across the ulnar aspect of the forearm to encircle the chest. During the application of this dressing, which is shown in the illustration, care must be taken not to rotate the forearm from its position directly in front of the arm and shoulder. If care is taken to cut away the lower edge of plaster the flexion crease can be exposed for care of the skin and this also permits good lateral *x*-ray films to be taken by introducing a film, not a casette, between the elbow and the side of the body. Warning must again be sounded that in using the hyperflexed position the quality of the radial pulse must be carefully observed. Our routine orders are: "Take pulse at wrist *on the splinted side* every half hour and report its absence or weakness immediately to the intern."

The extended forearm is a position for which there is only occasional need. Fractures of the olecranon may sometimes be so treated if operation is not done. There are also occasional instances of absent or feeble radial pulse in which the condition of the circulation is best observed by extending the forearm and elevating it on pillows. Straight wooden splints or by preference a plaster of Paris trough or gutter splint may be used.

Traction in Bed. The application of the traction may be by means of adhesive tape in the form of a Buck's extension, by a loop or sling of padded muslin or saddler's felt around the flexed elbow, by a pine or wire through the olecranon or by a screw hook inserted into the ulna opposite the coronoid. With adhesive traction the forearm may be extended and the strips applied the full length of forearm and arm, or the elbow may be flexed to any desired degree by applying one extension apparatus to the arm for traction and a second one to the forearm for suspension. A flexed position of the elbow is decidedly more comfortable for the patient. If a sling or loop be used great care must be taken to prevent undue pressure and frequent adjustments may be necessary to prevent the loop from slipping down along the forearm.

Skeletal traction through the olecranon presupposes the availability of necessary instruments and appliances, a careful aseptic technique in the introduction of the pin or wire and due care to avoid injury to the ulnar nerve. The screw hook as advocated by Cubbins and Callahan obviates the need for much equipment and the possibility of nerve injury but it does not dispense with the necessity for strict asepsis. Having secured attachment of the traction apparatus to the patient an external fixed point of attachment is required. An overhead frame is practically indispensable but need not be elaborate.

A hard flat mattress may support the arm without angulation but this may be assured by placing fracture boards between mattress and bedspring. Particularly if the patient is obese a Thomas splint with well adjusted hammocks between the side bars is advantageous. Traction and suspension have the advantage of offering an open type of fixation apparatus in which soft tissues may receive proper care and in which light massage, heat and active motion may all be practiced early.

CONVALESCENT TREATMENT

This has been touched upon in the discussion which has gone before but its importance is such that it warrants special emphasis. During the first few days soft tissue swelling often is a problem even though accurate reduction does much

toward causing its recession. At this stage radiant heat and gentle stroking massage have their greatest efficacy. Unfortunately their use is all too frequently reserved for a later period of treatment. Physiotherapy should begin with the reduction of, not the union of a fracture and should be used several times a day.

Dependency of the part should be avoided if the dressing will permit and, in cases with serious swelling, irrespective of the favored dressing. Blebs should be opened under sterile precautions after which they may be covered with tannic acid if desired. The surgeon must maintain a constant alertness to the dangers resulting from the pressure of tight or rigid dressings. Attention has been called to observing the integrity of the radial pulsations.

The time for institution of elbow movement depends upon the likelihood of displacing fragments. It should begin at the earliest possible date, meaning somewhere between the fifth to the tenth day. However, as much harm may result from too strenuous movement as from too prolonged immobilization. There is an ideal mean in which function is gradually regained without the interruptions occasioned by secondary trauma. No set rules can be given, but two general principles must be followed. First, it is the voluntary active movement of the patient which constitutes the major element in recovery. The surgeon may guide movements; he may support the weight of the extremity but he can not hasten matters by forcible passive motion or stretching under anesthesia. Indeed "pump handle" methods may do much harm. The patient must be impressed at the outset with the responsibility he carries for his own welfare and his confidence and coöperation must be obtained. It is only in the patients who fail to carry out their part of the scheme that a professional physiotherapist need be called upon in this particular group of fractures. To do so is not only an admission of failure but likely to be a poor substitution for a régime in which the patient works out his problems for himself. Second, the most reliable index of how much activity to allow at any stage of convalescence is the subjective reaction of the patient after exercise. It is almost inevitable that some pain may accompany the actual efforts to move a part which has been immobilized after injury. However, if pain continues as a persistent ache after exercise or if it is found that soreness of the part results in a decreasing rather than increasing range of motion, then the obvious conclusion is that exercise has been too strenuous or excessive and should be curtailed.

A favorable course is thus marked by the painless, progressive approach to a normal functional range. This implies the utmost gentleness in handling, no sudden jerks or forcible pressure and constant and persistent encouragement to bolster confidence and secure active cooperation. Children regain motion surprisingly if left to their own devices after danger of displacement or refracture is past. Special calisthenics are rarely needed and may be deleterious in fixing attention upon the disability. Adults may require various devices such as resistive exercises, climbing the wall with both hands, carrying weights in the hand or lifting them with a rope and pulley apparatus. The difference lies not only in the recuperative deficiencies of adult tissues but in the mental hazards, notably fear of pain and fear of further injury. In both groups continued improvement may be expected over a period of months and no functional disability should be regarded as permanent under one year.

CONCLUSION

Fractures about the elbow require thorough and accurate diagnosis which takes the soft parts into consideration as well as the bones, accurate restoration of displaced fragments, individuality of fixation dressings and judicious therapy designed to restore function at the end of convalescence. With proper attention to these

details the results in these cases should be good with very occasional exceptions.

REFERENCES

Cubbins, W. R., Callahan, J. J., and Scuderi, C. S. Compound fractures about elbow. *Am. J. Surg.*, 40: 627, 1938.

Eliason, E. L., and Johnson, Julian. Fractures about the Elbow, p. 566 in Christopher's Surgery. Phila. 1936. Saunders.

Eliason, E. L., Goldsmith, R., and Pendergrass, E. P. Fractures of the Humerus, Radius and Ulna. Phila., 1928. Lippincott.

Eliason, E. L., and McLaughlin, C. W. Fractures of the lower end of the humerus. *Am. J. Surg.*, 23: 79, 1934.

McLaughlin, E. F. Fracture of capitellum. *Proc. Phila. Acad. Surg.*, November 1938.

Speed, J. S., and Boyd, H. B. Fractures about the elbow. *Am. J. Surg.*, 38: 727, 1937.

Wilson, Philip. Fractures and dislocations of the elbow. *Surg., Gynec. & Obst.*, 56: 335, 1933.

It is commonly believed that the meat of young animals is more tender than that of the old. Actually the meat of the young animal is tougher. Meat is muscle, and muscles are tied up in tough tendons, sinews and other hard fibers. These tissues are indigestible. As the animal grows older and the muscles develop, the fibrous tissues thin out, making the meat more tender.

FRACTURES OF THE CARPAL (NAVICULAR) SCAPHOID

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CARPAL scaphoid fractures are not rare, but their true incidence seems indeterminable. Experiences vary: one writer finds an incidence of 8.7 per cent among hand fractures, while a second finds a far lower incidence. The practitioners among those of youthful activity, or of youth, will present high rates, while those of a different strata will find this disorder uncommon.

The mechanics of this fracture are disputed, and for this paper we see no advantage in reviewing them. It is sufficient and necessary to know that we have a fractured carpal scaphoid. An outstretched or dorsiflexed hand, and an intolerable pressure will bring a fracturing force through the third metacarpal and os magnum onto the immobilized scaphoid. Thus a waist fracture occurs. The extra- or intra-articular tuberosity fracture is an avulsion, beautifully exemplified by the diagram illustrating the optimum *x*-ray position in this paper. (Fig. 2.)

The scaphoid is not well-named: the old name—navicular or "boat-shaped"—fails to describe its anatomy, for no flight of imagination will make this bone look like a boat. The scaphoid is merely an elongated carpal, angled in its long axis through a few degrees and supplying most of the keystone of the wrist arch. And in the absence of this arch the wrist is very insecure indeed. Specifically, the bone consists of a body, a constricting waist, and a tuberosity, named in order from the proximal to the distal ends. The waist gives insertion to the radiocarpal ligaments and entrance to a varying number of blood vessels. Oblentz and Halstein (1938) find that 13 per cent have all their vessels at this constricted area; so fractures above the level, if we can believe the ischemia theory, are destined to nonunion in exactly that number. Lutzeler (1932), with equal emphasis, finds a proximal and distal blood supply, and no vascular reason for nonunion.

The five articulating surfaces of the carpal scaphoid leave little room for active osteogenic periosteum and hence little space for cortical bone repair. The physiologic senility of the wrist through its constant activity cannot encourage bone repair. The peculiar differentiation of the wrist synovia toward uncontrolled pannus formation hardly assists cartilage restoration or rehabilitation.

In discussing carpal scaphoid fractures, we must first arrive on a common ground. Is the fracture through the tuberosity, the waist, or the body? If it is through the tuberosity we can practically neglect it, for it will heal. If it is through the body it will not heal easily. It is small wonder that nearly as many treatments exist for fractured carpal scaphoids as there are carpal scaphoid fractures—and nearly as many conflicting results. If one speaks only of tuberosity fractures, all results are good; however, here we will speak only of waist or body fractures.

Why is this fracture troublesome, and why is it slow in healing? The theories are here shown—finally to be forgotten, since all we want is a painless wrist or bone union.

The first of the theories is embarrassment of the blood supply—Leriche and Policard (1928) maintain that this is a requirement of bone union. The next is the interposition of the radial-carpal ligament; Burnett feels that Adams is wrong in this. The constant bathing of the

fracture line by the physiologic lubricant-joint fluid may contribute to delay—although Johnston is erroneously believed

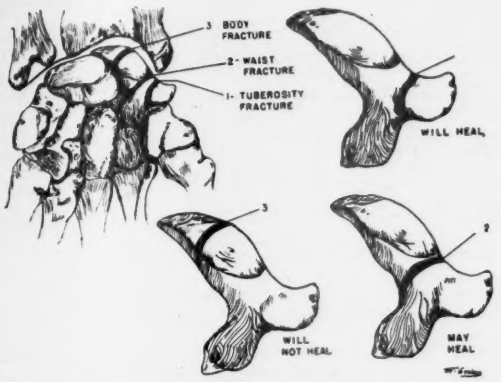

Fig. 1. Carpal region as viewed from palmar side. 1, Dark line indicates fracture through the tuberosity which heals with little or no treatment 2, Line indicates fracture through the scaphoid waist which may heal with little treatment. 3, Line indicates body fracture which will heal only under nearly ideal conditions.

to have shown this wrong. Johnston has shown how little the periosteum functions in the scaphoid region. Certainly, lack of fixation can be regarded as the least common denominator of all nonunions; on this must we pin our faith, and against this must we direct our treatment.

If we regard the carpal scaphoid mechanically, we will see that a great stress is brought in its upper pole. Here the wrist joint pries against the fragment, while the distal end of the scaphoid is fixed firmly between the os magnum and the radius. Motion, therefore, is most marked in the upper pole of the scaphoid, and here most nonunions occur.

Despite the effect of other and more nebulous factors, we have one firm belief: nonunion is predominantly the result of inadequate fixation, since all the mechanisms for nonunion are present in those carpal fractures which always unite —save free mobility.

In treatment, we must first find the fracture. There is no doubt, and we have some proof, that some body carpal fractures spontaneously unite. Some cases of healing are found at the autopsy table, and some are simply unreasonably prolonged "wrist sprains." Others will not be seen on the first *x*-ray plate and will be found only after rarefaction occurs,

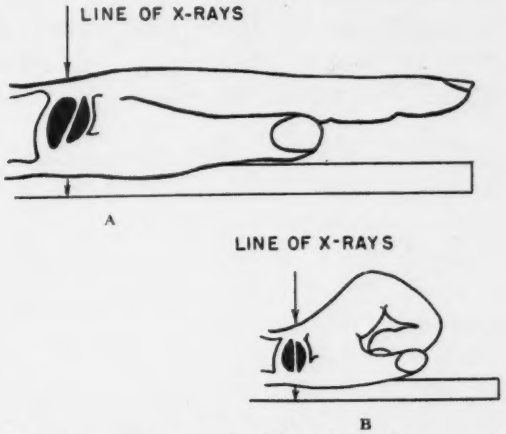

Fig. 2. A, mechanics of wrist with hand in neutral position. In this position, the scaphoid is so flexed that the fracture lines overly each other and may be missed on the *x*-ray plate. B, position of scaphoid with fist clenched. In this position, the usual scaphoid fracture lies in the same plane as the Roentgen rays. By using this position greater chance for fracture demonstration is possible.

while others will be suspected later by the cystic change which follows after impacted or cortical scaphoid fractures.

We recommend, and have found useful for *x*-ray diagnosis, the position advocated by Schnek. In this the wrist is dorsiflexed, and the hand pulled into radial deviation. This method exposes the scaphoid in its whole length, and eliminates overlying shadows. This we advocate, even if local anesthesia must be used to obtain it.

So far, nothing has been said about physical signs of early scaphoid fractures. To us they are of little importance, since wrist pain after trauma is an indication for Roentgen examination. Pain in the scaphoid region when the distal third metacarpal head is tapped, or pain over the snuffbox may indicate fracture, but only the Roentgen examination can prove it.

Before discussing treatment, we should note the possible congenital predilection toward fractures of the carpal scaphoid. Phitzner believes this, and we have evidence of this truth, since we know of four

cases of *bilateral* fracture of the carpal scaphoid. We must not be misled, however, by the bogey of bipartite scaphoids or persistent os centrales.

Although, as we have said, there are nearly as many treatments of carpal scaphoid fractures as there are fractures, treatment falls roughly into a few categories:

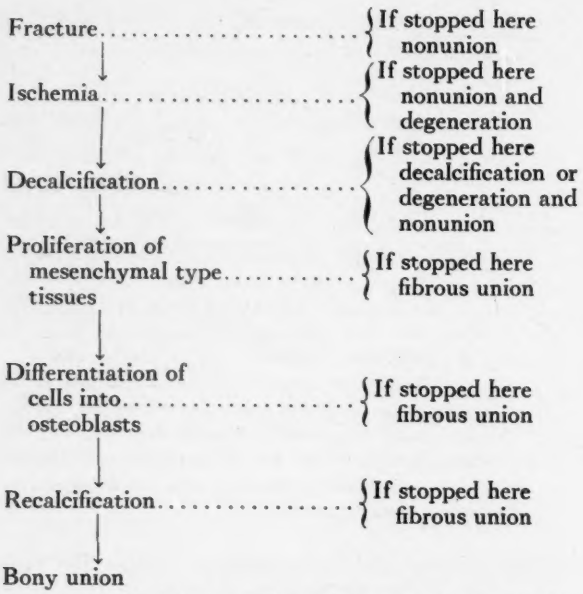

Chart 1. Nonunion, cystic degeneration, absorption, and fibrous union, are shown to be simply arrests at certain stages of the normal healing processes.

1. No treatment save physiotherapy.

2. Plaster fixation in volar and radial flexion (Speed); in volar and slight dorsal and ulnar flexion (Böhler); in volar and ulnar flexion (Destot); in dorsal flexion to 45 degrees with slight radial deviation (Berlin); in 30 to 40 degree extension, with the hand in complete radial flexion; and with the thumb in abduction and extension (Soto-Hall).

3. A combination of the above method supplemented by the use of a removable metal or leather splint to continue support and fixation. The time of fixation varies from three weeks to eight months.

4. The fractured scaphoid may be put in plaster in any of the above positions, and an irritant substance injected into the ancient fracture line.

5. The proximal or distal fragments may be removed, or the scaphoid may be entirely removed.

6. The center of the fractured scaphoid may be scooped out and allowed to replace itself, during a long fixation.

Treatment	First Week	Later Weeks	
Splint	1. Tuberosity fractures 2. Low waist fractures	1. Tuberosity fractures	
Fuse or fuse and drill	1. Upper waist fractures 2. Body fractures 3. Low waist fractures, if speed is essential	1. Low waist fractures 2. Upper waist fractures 3. Body fractures	If degenerative arthritis has not begun
Resect degenerated portion		1. If cystic degeneration or degenerative arthritis is present 2. If arthritis of radial articular surface is present	

Chart 11. Outline of treatment recommended for fractures, old and new, of the tuberosity, waist, and body of the carpal scaphoid.

7. The scaphoid may be drilled directly across the fracture line, thereby encouraging ingress of new blood vessels.

8. Autogenous bone grafts may be placed directly across the fracture (Smith, Adams).

From such a mass of conflicting treatments only confusion can come to the occasional operator. Certainly there must be some basic truths underlying these various therapies. We firmly believe the following: If the fracture is seen early, that is, within the first week, and if the break is through the waist or tuberosity, conservative treatment can be tried. Certainly the number of cures without treatment, or with seemingly inadequate fixation, confirms this belief. The exact position of this fixation seems to be of little importance, since nearly every hand position has been successfully used by different operators. It is important, of course, to reduce the fracture if the fragments have been displaced (though this is rare), and to hold them in such position as to prevent further distraction. We feel

that ulnar deviation should be avoided in tuberosity fractures, since this seems to be simply a repetition of the original methods of fracture. Dorsiflexion closes the gap between the fragments, and should the wrist become stiffened, allows the best working position. We recommend for these reasons the use of dorsiflexion and radial deviation. It has never seemed important to us to enclose the thumb, and or the index finger. The foregoing roughly sums up the so-called conservative treatment.

The fracture is held, in the case of tuberosity fractures, for three weeks in the above position. Should the fracture be through the low waist, under no circumstances should the fracture be removed from fixation in less than eight weeks, except after *x*-ray evidence of bone union. Some men prefer to use a removable metal splint for several weeks following the cast's removal. The necessity of this can be determined by the Roentgen plates taken during the sixth, seventh and eighth weeks.

So much for the so-called "conservative" treatment, although we should like to quarrel with the term "conservative." If an author means simply non-surgical treatment, why not state it as such? Conservative treatment, operative or nonoperative, is that treatment which will give the patient the best possible result in the shortest possible time. The above treatments apply only to low waist or tuberosity fractures seen within the first week.

All high waist or upper body fractures, or any other major fractures of the scaphoid a week or more old, except those through the tuberosity, fall in one class, and for these we believe only one treatment can be safely prescribed. Here we may well quote Todd: "One fact emerges most clearly, namely, that all methods of late treatment are uncertain and unsatisfactory." This statement, made only one year ago, must be given proper weight. The simple fixation of late or complicated cases cannot be regarded as conservative treatment; this is radical treatment, since the results are foreordained to be unsatisfactory.

In the above cases (i.e., complicated or ancient fractures) the scaphoid must be exposed surgically, and an autogenous bone graft passed through from the distal to the proximal fragment. Lately we have modified this by making several drill holes in the fragments across the fracture line, but pass the graft through only one of these. By this method we get good fixation and eliminate a possible cause of nonunion by enhancing blood supply. The hand is then put up in acute dorsiflexion and radial deviation, and is so held for eight weeks. By this method good results have been obtained in fourteen out of fifteen high carpal scaphoid fractures. Only one has shown any residual disability. Seven have united by bony union, but by reason of surgical abuse of the cartilage of the radius or because of an undiscovered arthritis present at the time of the operation, one wrist is limited to 50 per cent of its motions and is painful on attempted motions beyond those points. Such a fracture, were this cartilaginous damage and this injury found at the time of this operation, would have been better treated by removal of the proximal fragment. In other words, if a degenerative type of arthritis has already set in, no bone grafting or drilling will restore such a wrist to normal.

If one wishes to be absolutely certain of the result in waist fractures, then, even though these are less than a week old, he should join the fragments with a bone graft. This gives the patient the best possible chance for recovery. If the fracture is through the body, bone grafting should be done immediately. If the fracture is more than one week old, and is anything but a simple tuberosity fracture, bone grafting should be done. For ancient ununited fractures, with a degenerative arthritis, only removal of the proximal fragments will permit a cure. In all other fractures, simple fixation will be sufficient.

SUMMARY

1. It is intended in this paper to divide scaphoid fractures as to age and location,

i.e., they are either less or more than one week old—and fractured through the tuberosity, the waist, or the body, and are or are not the site of a degenerative arthritis.

2. A reliable and positive *x*-ray method for detecting these fractures is shown.

3. We advise plaster or splint fixation only in tuberosity fractures, regardless of duration.

4. In low waist fractures, we advise or tolerate plaster or splint fixation in those less than one week old.

5. Drilling and bone pegging are used in all high waist and body fractures regardless of age—unless degenerative arthritis has already set in.

6. Resection of the degenerated fragment is done in those fractures already afflicted by degenerative arthritis.

7. Finally, in any case of fractured carpal scaphoid, when speed and assurance of a good result are necessary (except in those fractured through the tuberosity or those who have already developed a degenerative arthritis), we unqualifiedly advise bone drilling and grafting of the affected carpal.

REFERENCES

(Articles classified by subject predominance)

Treatment

Adams, J. D., and Leonard, R. D. Fracture of carpal scaphoid; new method of treatment with report of one case. *New England J. Med.*, 198: 401–404 (April 12) 1928.

Aleman, O. Ein Beitrag zur Behandlung der Fractura ossis navicularis carpi. *Acta chir. Scandinav.*, 80: 217–237, 1937.

Belot, M. Traumatismes carpiens successifs. Malacie et fracture secondaires du scaphoïde (maladie de Köhler-Mouchet). *Rev. d'ortbop.*, 19: 553–557 (Sept.-Oct.) 1932.

Bergerhoff, W. Fraktur des Os naviculare manus sin. oder angeborene Missbildung. *Röntgenpraxis*, 7: 544–546 (Aug.) 1935.

Berlin, D. Position in treatment of fracture of carpal scaphoid. *New England J. Med.*, 201: 574–579 (Sept. 19) 1929.

Biancheri, T. M. Le lesioni traumatiche del carpo. *Chir. d. org. di movimento*, 4: 347–392, 1920.

Bizarro, A. H. Traumatology of the carpus. *Surg., Gynec. & Obst.*, 34: 574–588, 1922.

Blencke, H. Bruch des Kahnbeines der rechten Hand durch falsches Abwehren eines Fussballese. *Sportmedizin*, 1: 19 (May) 1929.

Boerema, I. Über die Pseudarthrose des Os naviculare manus. *Arch. f. ortbop. u. Unfall-Chir.*, 38: 42–53, 1937.

Bonnet, G., and Sarroste, J. Les séquelles de la fracture du scaphoïde carpien (fracture du gymnaste) (d'après 16 observations, suivies à longue échéance). *Rev. de chir.*, 50: 267–296 (April) 1931.

Bordona, J. M. S., and Lope. de la Garma, F. Consideraciones sobre veinticinco casos de fractura del Escafoides Carpiano. *Progresos de la clin.*, 41: 109–117 (Feb.) 1933.

Brandis, W. Übersehener Kahnbeinbruch. *Med. Klin.*, 25: 993 (June 21), 1929.

Brodersen, N. H. Treatment of fracture of carpal scaphoid by Böhler's method. *Norsk mag. f. laegevidensk.*, 92: 145–147 (Feb.) 1931.

Brown, K. P. Fracture of navicular. *Brit. M.J.*, 1: 591–592 (April 7) 1928.

Burnett, J. H. Fractures of carpal scaphoid. *New England J. Med.*, 200: 126–127 (Jan. 17) 1929.

Burnett, J. H. Fracture of the (navicular) carpal scaphoid. *New England J. Med.*, 211: 56–60, (July 12) 1934.

Burnett, J. H. Fracture of the (navicular) carpal scaphoid. *Surg., Gynec. & Obst.*, 60: 529–531 (Feb.) 1935.

Burnett, J. H. Further observations on treatment of fracture of carpal scaphoid (navicular). *J. Bone & Joint Surg.*, 19: 1099–1109 (Oct.) 1937.

Cauli, G. Lesioni traumatiche del carpo (contributo casistico). *Riv. ospedal.*, 9: 521, 1919.

Charbonnel and Lafargue. Trois cas de traumatismes fermés du carpe. *J. de méd. de Bordeaux*, 1: 19, 1920.

Christopher, F. Fracture dislocation of right carpus. *S. Clin. North America*, 15: 597–599 (June) 1935.

Clery, A. B. Fracture of scaphoid with dorsal dislocation of distal fragment of that bone and of distal carpal row. *Irish J. M. Sc.*, pp. 372–373 (Aug.) 1926.

Codman, E. A., and Chase, H. M. The diagnosis and treatment of fracture of the carpal scaphoid and dislocation of the semilunar bone; with a report of 30 cases. *Pub. Mass. Gen. Hosp.*, 1906.

Cole, W. H., and Williamson, G. A. Fractures of the carpal navicular bone. *Minnesota Med.*, 18: 81–83 (Feb.) 1935.

Cornejo Saravia, E. Fractura del escafoides. *Bol. y. trab. de la Soc. de cir. de Buenos Aires*, 14: 821–829 (Oct. 29) 1930.

Cravener, E. K. Fracture of (navicular) carpal scaphoid. *New York State J. Med.*, 35: 807–809 (Aug. 15) 1935.

Cros, J. M. Contribution à l'étude des fractures isolées du scaphoide carpien. Paris, 1930.

Dariaux, A. Luxation du semi-lunaire et fracture du scaphoïde. *J. de radiol. et d'électrol.*, 14: 457 (Aug.) 1930.

Davidson, Arthur J., and Horwitz, M. T. An evaluation of excision in the treatment of ununited fracture of the carpal scaphoid (navicular) bone. *Ann. Surg.*, 108: 291–295 (Aug.) 1938.

Degueldre and Duchene. Fracture comminutive du scaphoïde carpien, *Arch. méd. belges*, 83: 305–309 (May) 1930.

Elliott, C. C. Fracture of navicular bone (scaphoid). *J. M. A. South Africa*, 3: 403 (July 27) 1929.

Ferguson, L. K. Fractures of the carpal scaphoid. *S. Clin. North America*, 17: 1603–1611 (Dec.) 1937.

Ferrero, V. Contributo allo studio delle fratture isolate dello scafoide del carpo de causa diretta. *Chir. d. org. di movimento*, 12: 525–530 (Aug.) 1928.

Feutelais, P. Fracture du scaphoïde carpien d'apparence spontanée. *Rev. d'orthop.*, 19: 230–236 (May-June) 1932.

Forster, A. Le scapho-semi-lunaire. Étude comparative de la stabilisation du carpe chez les mammifères et chez l'homme. *Arch. d'anat., d'histol. et d'embryol.*, 15: 81–217, 1932.

Foucalt, P. Les lesions du carpe au cours des traumatismes du poignet. *Arch. méd. chir. de Provence*, 14: 313–319, 1924.

Frosch, L. Beiträge zu den Frakturen des Os naviculare manus, *Verhandl. d. deutsch. orthop. Gesellsch.*, 25: 189–192, 1931.

Gabrielle, H. Fracture du scaphoïde avec dislocation du carpe et fracture bi-styloïdienne. *Lyon chir.*, 26: 753–755 (Sept.-Oct.) 1929.

Gold, E. Zur Frage der konservativen Behandlung der intraartikulären Brüche des Os naviculare carpi. *Beitr. z. klin. Chir.*, 140: 215–258, 1927.

Grace, R. V. Fracture of carpal scaphoid. *Ann. Surg.*, 89: 752–761 (May) 1929.

Harild, S. Isolated fracture of carpal scaphoid. *Ugesk. f. laeger.*, 92: 545–548 (June 5) 1930.

Hartmann. Fracture de scaphoïde et phénomènes d'arthrite chronique de poignet. *Rev. gén. de clin. et de thérap.*, 41: 133 (Feb. 26) 1927.

Hirsch, Maximilian. Konservative oder operative Therapie der Fraktur des Os navicular carpi. *Wien. med. Wchnschr.*, 85: 803–804 (July 13) 1935. Comment by Böhler. *Wien. med. Wchnschr.*, 85: 1085–1086 (Sept. 28) 1935. Reply by Hirsch. *Wien. med. Wchnschr.*, 85: 1086 (Sept. 28) 1935.

Hirsch, M., and Goldhammer, K. Beitrag zur Frage der Heilungsmöglichkeiten des Kahnbeinbruches. Anatomischröntgenologische Studie. *Arch. f. klin. Chir.*, 151: 793–804, 1928.

Hoffmeister, W. Behandlung von Kahnbeinbrüchen und Pseudarthrosen. *Zentralbl. f. Chir.*, 61: 2960–2963 (Dec. 22) 1934.

Hook, F. R., and Boone, J. D. Fracture of carpal scaphoid. *U. S. Nav. M. Bull.*, 34: 172–181 (April) 1936

Hosford, J. P. Fractures of the carpal scaphoid. *St. Barth. Hosp. Rep.*, 68: 201–207, 1935.

Huard, P., and Boutareau. Trois cas de fracture du scaphoïde carpien opérés. *Bull. Soc. Med.-chir. de l'Indochine*, 15: 428–433 (April) 1937.

Jacquet, H. Scaphoïde carpien pommelé, douloureux (résultat opératoire et examen anatomique de la pièce extirpée). *Bull. et mém. Soc. nat. de chir.*, 58: 1361–1363 (Nov. 26) 1932.

Johnson, J. A. W. Fracture of carpal scaphoid with report of case. *J. Iowa M. Soc.*, 25: 307–309 (June) 1935.

Jonckheere, F., and Smets, W. Traitement des fractures récentes au scaphoïde carpien et de leurs complications. *J. de chir. et ann. Soc. belge de chir.*, 36–34: 183–211 (May) 1937.

Kaisinger, O. Ueber sogenannte sekundäre Frakturen und Pseudarthrosen des Os naviculare. *Marb.*, 1935.

Kapel, O. Therapy of ununited fractures of carpal scaphoid bone. *Hospitalstid.*, 75: 954–958 (July 21) 1932.

Krajewski, F. Fractures of carpal navicular bone. *Chir. narz. ruchu*, 5: 45–48 (Jan.-March) 1932.

Kuegle, F. H. Fracture of the carpal scaphoid. *Wisconsin M. J.*, 36: 631–632 (Aug.) 1937.

Leavitt, D. G., and Leavitt, H. L. Carpal fracture dislocation. *Northwest Med.*, 35: 178–179 (May) 1936.

Lindon, L. Certain injuries in the region of the wrist joint. *Australas. Nurses' J.*, 22: 460; 503, 1924.

Macmillan, Francis B. Injuries to the carpal bones. With particular reference to the carpal scaphoid. *Am. J. Surg.*, 42: 633–637 (Dec.) 1938.

Magliulo, A. Contributo allo studio della fratture isolate ed associate dello scafoide carpale e loro trattamento. *Arch. di ortop.*, 43: 536–572, 1927.

Magliulo, A. Sulle fratture isolate medio-transversali dello scafoide del carpo con speciale riguardo ai loro esiti. *Arch. ital. di. chir.*, 20: 641–660, 1928.

Matti, H. Uber die Behandlung der Naviculare fraktur und der Refractura patellar durch Plombierung mit Spongiosa. *Zentralbl. f. Chir.*, 64: 2353–2359 (Oct. 9) 1937.

Ménard, L. Fracture ancienne partiellement consolidée du scaphoïde du poignet gauche. *Paris méd.*, 1: 115 (Jan. 29) 1927.

Menegaux, G. Séméiologie des lésions traumatiques du carpe. *Presse méd.*, 41: 915–916 (June 7) 1933.

Minina, R. M. Fractures of navicular bone. *Soc. krir.*, pp. 833–836, Nov. 11, 1936.

Moraes, Fernando de. Fractura do escaphoids carpiano em um jovende 16 annos. *Brasil med.*, 51: 747–749 (July 10) 1937.

Moseley, H. F. Non-union of carpal scaphoid. *St. Thomas's Hosp. Rep.*, 1: 178–180, 1936.

Mouchet, A. Fractures isolées du scaphoïde carpien. *Presse méd.*, 42: 121–122 (Jan. 20) 1934. Also *Gaz. d. osp.*, 55: 393–397 (April 1) 1934.

Mouchet, A. Fracture du scaphoïde carpien (douvant être prise par une anomalie congénitale) (Naviculare carpi bipartitum). *Ann. de méd. lég.*, 16: 307–310 (June) 1936.

Mouchet, A. Fracture ancienne du scaphoïde carpien méconnue et révéler par un accident recent. *Ann. de méd. lég.*, 16: 577–579 (Nov.) 1936.

Mouchet, Jeanne, and Mouchet, A. Étude clinique thérapeutique des lésions traumatiques du carpe. *Bull. méd.*, 33: 603–605, 1919.

Mumford, E. B. Fracture of navicular (carpal) bone. *J. Indiana M. A.*, 22: 56–58 (Feb.) 1929.

Murard, J. Luxation subtotale rétrolunaire du carpe avec fracture du scaphoïde. Intervention sanglante. Résection secondaire totale du carpe. *Bull. et mém. Soc. nat. de chir.*, 57: 826–829 (June 6) 1931.

Murray, D. W. G. Fractures of carpal scaphoid. *Canad. M. A. J.*, 34: 180–182 (Feb.) 1936.

Murray, G. Bone-graft for non-union of carpal scaphoid. *Brit. J. Surg.*, 22: 63–68 (July) 1934.

Murray, G. Bone-graft for non-union of the carpal scaphoid. *Surg., Gynec. & Obst.*, 60: 540–541 (Feb.) 1935.

Neuhöfer, P. Beitrag zur Klinik der Verletzungen im Bereiche des Carpus. *Beitr. z. klin. Chir.*, 128: 730–753, 1923.

Nicolis, S. Contributo allo studio delle lesioni traumatiche del carpo. *Radiol. med.*, 10: 328–331, 1923.

Nitsche, F. Zur Behandlung der Kahnbeinbrüche. *Zentralbl. f. Chir.*, 64: 323–324 (Feb. 6) 1937.

Obletz, B. E., and Halbstein, B. M. Non-union of fractures of carpal navicular. *J. Bone & Joint Surg.*, 20: 424–428 (April) 1938.

Paal, E. Isolierte Luxationsfraktur des Od naviculare, ein Beitrag zu den saltenen Verletzungen der Handwurzel. *Zentralbl. f. Chir.*, 61: 1282–1284 (June 2) 1934.

Paitre, F. R. C. De quelques lésions traumatiques du carpe en marge des données classiques. *Arch. de méd. at pharm. mil.*, 83: 403–439, 1925.

Parneix. Les fissures et les fractures isolées du scaphoïde carpien. *Arch. de méd. et pharm. nav.*, 126: 472–542 (July-Sept.) 1936.

Péraire, M., and Chabry, L. Quelques cas de fractures et luxations simples et complexes des os du carpe. *Paris chir.*, 11: 108–110, 1919.

Perardi, G. Le fratture dello scafoide del carpo. *Policlinico* (sez. prat.), 41: 1827 (Nov. 19) 1934.

Perez-Lorie, J. Un caso de fractura de escaphoides carpiano y del hueso grande. *Cir. ortop. y. traumatal.*, 5: 125–130 (Apr.-June) 1937.

Poland, H. Zur Behandlung der Pseudarthrose des Kahnbeins an der Hand. *Chirurg.*, 7: 245–249 (April 15) 1935.

Rochet, P. Subluxation rétro-lunaire du carpe avec fracture du scaphoïde. Reduction. Mobilisation précore. *Lyon chir.*, 33: 97 (Jan.-Feb.) 1936.

Roederer, C. Evolution intéressante d'une fracture du scaphoïde carpien. *Bull. et mém. Soc. chir. de Paris*, 24: 382–385 (June 17) 1932.

Rostock, P. Uber die Navicular-Pseudarthrose. *Arch. f. ortbop. u. Unfall-Chir.*, 34: 318–320, 1933.

Rostock, P. Die Naviculare-Pseudarthrose. *Arch. f. ortbop. u. Unfall-Chir.*, 35: 193–223, 1935.

Schär, W. Röntgenologische Veränderungen nach Navikularefrakturen der Hand und ihre klinische Bedeutung. *Schweiz. med. Wchnschr.*, 60: 1079–1081 (Nov. 15) 1930.

Schnek, F. Die Behandlung der verzögerten Callusbildung des Os naviculare manus mit der Beck'schen Bohrung. *Zentralbl. f. Chir.*, 57: 2600–2603 (Oct. 18) 1930.

Schnek, F. G. Konservative oder operative Therapie der Fraktur des Os naviculare carpi. Bemerkungen zur Arbeit von Maximilian Hirsch. *Wien. med. Wchnschr.*, 86: 488–489 (May 2) 1936.

Schoonbrood. Etude des lésions spontanées et traumatiques des os spongieux en marge d'une description des fractures du scaphoïde carpien. *Arch. belges de méd. mil.*, 91: 6–19 (Jan.) 1938.

Schrader, E. Zur Diagnostik des Kahnbeinbruches der Hand. *Monatschr. f. Unfallh.*, 38: 266–268 (June) 1931.

Smith, E. H. Autogenous bone dowel for relief of fracture of scaphoid bone of wrist. *Med. Rec.*, 139: 655–656 (June 20) 1934.

Solcard, and Guichard. Trois cas de fractures des os du carpe. *Bull. et mém. Soc. nat. de chir.*, 53: 1345–1349 (Dec. 17) 1927.

Soto-Hall, R., and Haldeman, K. O. Treatment of fractures of carpal scaphoid. *J. Bone & Joint Surg.*, 16: 822–828 (Oct.) 1934.

Speed, K. The fate of the fractured carpal navicular. *Tr. Am. Surg. A.*, 42: 244–54, 1924. Also *J. Bone Surg.*, 7: 682–695, 1925.

Speed, K. Traumatic Injuries of the Carpus, Including Colles's Fracture. New York, 1925.

Spick and Rocques. Fractures du scaphoïde carpien. *Arch. de méd. et pharm. mil.*, 94: 463–469 (March) 1931.

Tanton, J. A propos de quelques traumatismes du carpe. *Bull. et mém. Soc. de chir. de Par.*, 41: 2131–2137, 1915.

Tecce, E. Le fratture dello scafoide carpale. *Rinas. med.*, 12: 514–515 (Dec. 15) 1935.

Tecce, E. Le fratture dello scafoide carpale. *Rassegna di med. appl. lavoro indust.*, 7: 114–120 (April) 1936.

Thompson, J. E. Fractures of the carpal navicular and triquetrum bones. *Am. J. Surg.*, 21: 214–226 (Aug.) 1933.

Torpy, C. D. Case of fracture-dislocation of carpal scaphoid (navicular). *Indian M. Gaz.*, 65: 18 (Jan.) 1930.

Tribout, F., and Aubourg. A propos d'une lésion du carpe. *Bull. et mém. Soc. de radiol. méd. de France*, 7: 117, 1919.

Trueta Raspall, J. Contribución al estudio de las fracturas aisladas del escafoides del carpo. Según la experiencia recogida en lo casos personales. *Ars. méd.*, 5: 15–21 (Jan.) 1919.

Ulrich. Alte Kahnbeinfraktur. *Röntgenpraxis*, 9: 130 (Feb.) 1937.

Wassom, G. N. Injuries to the carpal bones. *Railway S. J.*, 22, 148–154, 1915–1916.

Westermann, H. H. Die Therapiefrage der Navicularefraktur. [Frankfurt.] Gött., 1933.

Westermann, H. H. Die Behandlung der Pseudarthrose des Kahnbeines der Hand. *Monatschr. f. Unfallh.*, 43: 287–294 (June) 1936.

Woods, R. S. Union of carpal scaphoid (by immobilization) after six weeks delay in treatment. *Brit. M. J.*, 2: 1119–1120 (Dec. 4) 1937.

Woughter, Harold W. Conservative treatment of carpal bone injuries. *Indus. Med.*, 7: 494–497 (Aug.) 1938.

Yersin, C.-G. Dislocations du poignet, fractures du scaphoïde, luxations du semi-lunaire. *Rev. méd. de la Suisse Rom.*, 37: 627–637, 1917.

Zakov, S. B. Fractures of the carpal scaphoid bone. *Novy khir. arkhiv.*, 39: 514–526, 1937.

Zwerg, H. G., and Heidemann, H. Navicularfrakturen, Navicularcysten und Pseudarthrosen. Eine Nachunterschung. *Arch. f. klin. Chir.*, 185: 395–427, 1936.

Pathology.

Andreersen, R. Aseptische Nekrose des Od naviculare ulnare manus. *Zentralbl. f. Chir.*, 64: 393–395 (Feb. 13) 1937.

Dubois, M. Der Mechanismus der Fraktur des Navikulare und die Pseudarthrosenbildung. *Schweiz. med. Wchnschr.*, 60: 1074–1076 (Nov. 15) 1930.

Flandin, C., Poumeau-Delille and Van Bogaert, A. Un cas de causalgie avec syndrome de Raynaud et érythromelalgie post-traumatique. *Bull. et mém. Soc. méd. d. hôp. de Paris*, 47: 1293–1296 (July 13) 1931.

Haehner. Doppelseitige nichttraumatische Zweiteilung des Kahnbeins? *Monatschr. f. Unfallh.*, 39: 210–221 (May) 1932.

Herzenberg, L. Diseases and injuries of carpal bones. *J. M. A. South Africa*, 5: 481–482 (Aug. 8) 1931.

Johnson, R. W., Jr. Study of healing processes in injuries to carpal scaphoid. *J. Bone & Joint Surg.*, 9: 482–497 (July) 1927.

Lutzeler, H. Die Entstehungsursache der Pseudarthrose nach Bruch des Kahnbeins der Hand. *Deutsche Ztschr. f. Chir.*, 235: 450–467, 1932.

Pfab, B., and Zöllner, F. Zur Pathologie der Handgelenkverletzungen. Naviculare frakturen, bzw. Pseudarthrosen mit Cystenbildung. Lunatumluxationen. Lunatummalacien. *Deutsche Ztschr. f. Chir.*, 233: 355–386, 1931.

Schnek, F. Verwechslung des Kahnbeinbruches mit Handgelenkstuberkulose. *Zentralbl. f. Chir.*, 56: 1683–1685 (July 6) 1929.

Torpy, C. D. Fracture of carpal scaphoid—radiological study of 30 cases. *Indian M. Gaz.*, 67: 265–266 (May) 1932.

Diagnostic and X-ray Methods.

Biancheri, T. M. L'indagione radiologica nelle lesioni traumatiche del carpo. *Radiol. med.*, 7: 110, 1920.

Bonnet. Fracture ancienne du scaphoïde sans signes radiologiques pendant neuf mois. Signes radiologiques actuels et séquelles. *Soc. de méd. mil. franc., Bull. mens.*, 23: 60–62, 1929.

Jacobsen, E. Zur röntgenologischen Diagnose von Kahnbeinbrüchen der Hand. *Zentralbl. f. Chir.*, 60: 495–500 (Mar. 4) 1933.

Perschl, A. Zur röntgenologischen Diagnostik der frischen Kahnbeinbrüche der Hand. *Röntgenpraxis*, 10: 11–16 (Jan.) 1938.

Preiss, G. A. Ueber eine schwer diagnostizierare Navikularefraktur. *Schweiz. med. Wchnschr.*, 65: 105 (Jan. 26) 1935.

Schnek, F. Zur Diagnostik der Kahnbeinbrüche der Hand. *Monatschr. f. Unfallh.*, 38: 103–108 (March) 1931.

Schnek, F. Zur Röntgenologischen Diagnose von Kahnbeinbrüchen der Hand. *Zentralbl. f. Chir.*, 60: 1954–1956 (Aug. 19) 1933.

Schreuder, O. Roentgen-rays diagnosis of fracture of scaphoid bone of carpus. *Nederl. Maandschr. v. Geneesk.*, 13: 292–294, 1925.

Stecher, W. R. Roentgenography of carpal navicular bone. *Am. J. Roentgenol.*, 37: 704–705 (May) 1937.

Statistical Studies.

Carter, R. M. Statistical results of the radiographic study of injuries about the wrist-joint. *Ann. Surg.*, 81: 532–535, 1925.

Hopkins, F. S. Fractures of the scaphoid in athletes. *New England J. Med.*, 209: 687–690 (Oct. 5) 1933.

Hosford, J. P. Prognosis in fractures of carpal scaphoid. *Proc. Roy. Soc. Med.* (Sect. Surg.), 24: 92–94 (May) 1931.

Moulonguet, P. Une série de traumatismes du carpe. *Bull. et mém. Soc. anat. de Paris*, 92: 407–413, 1922.

Page, C. M. Cases of injury to the carpal bones. *Proc. Roy. Soc. Med.*, Sect. Clin.), 14: 38–43, 1920–1921.

Snodgrass, L. E. End results of carpal-scaphoid fractures. *Ann. Surg.*, 97: 209–216 (Feb.) 1933.

THE DIAGNOSIS AND TREATMENT OF FRACTURES OF THE PELVIS AND THEIR COMPLICATIONS*

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OUR primary object in this presentation on the subject of fractures of the pelvis is to point out the essential features embodied in the recognition and treatment of a major surgical problem. A comprehensive review of 255 cases treated on our service since 1916 has provided ample opportunity for study of this condition in all its phases. The increase in number, occasioned by new methods of transportation and other recent industrial developments, no longer places this type of injury among the rarer fractures. Recent surveys show that it constitutes over 3 per cent of all skeletal fractures.

The normal anatomic relationship of the pelvis in maintaining its specific functions of the body is so well established and so important that any disturbed continuity of its parts should receive every effort for restoration of good alignment. The amazingly high mortality, which varies from 10 to 30 per cent, should attract the attention of the entire medical profession.

Successive advances in surgery have been followed by improvements in the mortality rate of this injury during each decade. A review of the literature by E. P. Quain in 1916 showed that prior to 1890 the mortality rate was 86.7 per cent; from 1890 to 1905 this dropped to 48 per cent and from 1905 to 1916 to 38 per cent. A recent review shows a consistent improvement, especially among the larger clinics, where clinical facilities undoubtedly offer better opportunities for the institution of proper therapy.

Much can also be said of the increased knowledge pertaining to the early recognition of this type of fracture and the establishment of first aid service for safe transportation.

Restoration of function in fractures of the pelvis is so important in order to avoid disturbed function of the neighboring viscera, that one should have a clear understanding of the essential purpose and the position which the pelvis occupies in the anatomical structure of the human body.

The pelvis is composed of the innominate bones on either side with the sacrum and coccyx posteriorly. It is divided into two chambers, the false pelvis above the iliopectineal line and the true pelvis below. It serves the very important task of protection and support of the pelvic and abdominal viscera, and also as a connecting link between the trunk and the lower limbs. It serves as a weight bearer between the trunk and the lower limbs, in addition to supplying means for locomotion. It also affords points for the attachment of the many muscles and ligaments, which control the movements of the lower limbs, which, under normal conditions, maintain proper balance and equilibrium of the body. The pelvis supports the trunk in two postures, standing and sitting. In the standing posture the weight is transmitted through the acetabulum, and in the sitting posture through the tuberosities of the ischium.

The bony pelvis is composed of two main arches, the femorosacral and the ischiosacral. These are further strengthened and anchored by two subsidiary arches,

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which join the extremities of the main ones.

The configuration of the pelvic ring presents points of special weakness, which are situated as follows: (1) midway between the symphysis pubis and the acetabulum; (2) the symphysis pubis; and (3) a trifle external to both sacroiliac joints. These areas seem most susceptible to the strain of violence and a solution of continuity is found most frequently in these locations.

It is by virtue of experience from year to year, by knowledge obtained from the literature and, by contact with others, that improvement is attained in the early diagnosis and treatment of such major injuries as fractures of the pelvis. By the same token, a reduction in the permanent disabilities and mortality rate can only be obtained by an earnest effort of the surgeon and his well organized associates in recognizing fractures of the pelvis as acute emergency surgical problems.

In the simpler forms of fracture, involving one of the rami on either side, or a moderate separation of the symphysis, without loss of continuity of the pelvic ring, only mild physical complaints may be recorded. The patient may be capable of balance and walking, but with some difficulty and pain over the inguinal region, symphysis and perineal area, and with some discomfort over the lumbosacral region. A history of some form of trauma or pelvic compression should immediately arouse one's suspicion of possible pelvic injury. A physical examination will reveal difficulty in hyperflexion of the thighs upon the abdomen, even though it may be complete and more marked on one or the other side. There may be tenderness in the perineal region, especially over the adductor muscles, with tenderness about the symphysis and along the margin of the inguinal canal. The most outstanding physical sign, and probably the most important diagnostic aid, is found upon lateral compression of the iliac crests or hip joints with the palm of the hand. One immediately feels a giving sensation, which is not infrequently associated with crepitation. This is always accompanied by pain or distress when a fracture exists or when a separation of the symphysis has occurred. Occasionally the separation of the symphysis has become approximated, as found by *x*-ray. However, a positive compression sign still shows evidence of previous separation and trauma. Roentgenograms should always be taken upon the least suspicion of pelvic injury.

Occasionally intestinal ileus occurs in the milder injuries and may reach severe proportions when treatment is delayed. Its recognition depends upon the degree of distention present and whether peristalsis is subdued or absent. We always presuppose its development and institute therapeutic measures immediately.

Even though the physical findings of fracture are apparently mild, one should always be mindful of latent complications, especially those involving the genitourinary tract.

The severer forms of fracture present a vastly different picture. The symptoms and physical signs involve changes directly the result of pelvic injury plus those arising from associated injuries to other viscera. The pelvic damage may constitute only a wide separation of the symphysis with extensive soft tissue damage to the membranous or posterior urethra and surrounding structures. This may be associated with separation of one or both sacroiliac areas with or without marked displacement, or the fracture may involve one or more rami with or without displacement. Less frequent, but more destructive, is a vertical, or fracture of Malgaigne, constituting a complete solution of continuity of anterior and posterior rings, with or without displacement.

The symptoms and physical diagnostic findings in such cases usually are the following: The patient frequently presents a picture of shock in varying stages, the degree of which should immediately be determined by blood pressure readings, etc.

It may occasionally be delayed. Treatment should be instituted accordingly.

The patient is frequently unable to demonstrate proper function of one or both lower limbs by voluntary elevation while reclining. This attempt is always painful about the groin, inguinal and pubic regions. The elevation, however, may be complete, partial or absent. Observation of the pelvic structure may show a distortion, representing displacement at the symphysis, rami or posterior ring. The bladder may be found distended upon observation and percussion. The abdomen may already show a distention with apparent muscular resistance.

Lateral compression of the iliac crests or hip joints with the palm of the hands imparts a giving sensation, showing a lack of firmness and, frequently elicits a sense of crepitation which is always accompanied by certain degrees of pain and discomfort. Gentle palpation produces tenderness along the inguinal canal, the symphysis and the perineal region, occasionally over the bladder, buttocks and sacroiliac regions. The abdomen is generally resistant, but localized tenderness is rare unless some intra-abdominal injury has been sustained. Auscultation reveals subdued or absent peristalsis, indicating the presence of a paralytic intestinal ileus, especially in severe types. This is frequently mistaken for ruptured viscus.

Rectal examination may occasionally show pressure of a fragment upon the rectal wall or a rupture by a sharp spicule of bone. The patient is often temporarily unable to void even in the absence of any urethral damage. When urethral damage is present, in the form of either moderate laceration of the mucosae or rupture, there always appears some evidence of blood at the urethral orifice. This is a valuable diagnostic aid. Further investigation as to the extent of damage should then be performed by catheterization under strict asepsis. Extravasation of hemorrhage or urine into the surrounding soft tissues may occur gradually or rapidly and its diffusion depends on the point of rupture above or below the fascial planes of the pelvis. Evidence of its presence may be observed over the bladder and lower abdominal wall, perineum or scrotum. Cellulitis following the extravasation of urine may extend rapidly over the above regions with febrile symptoms and acute toxemia.

Evidence of gas bacillus infection, developing after a rupture of the rectal wall, which develops at an early date, should always engage one's thought following the early hours of injury. The presence of a bluish-brown, discolored form of cellulitis of the skin and subcutaneous tissues, spreading over the perineum, scrotum and abdominal wall, with emphysema present upon palpation, and associated acute toxic symptoms, point definitely to its presence.

Intraperitoneal rupture of the bladder is always associated with distention and ileus and other definite findings pointing to a peritoneal irritation. The muscles, in the early stages, are palpated easily but shortly become resistant and rigid with the presence of fluid in the flanks in contrast to the physical findings of paralytic ileus. Abdominal paracentesis, as advised by one writer, as an aid to diagnosis, is a dangerous procedure, and I rather feel its practice is to be discouraged, except in extreme doubt.

As a final diagnostic measure, one can always obtain definite information by simple aseptic catheterization of the bladder, which will demonstrate the presence or absence of hemorrhage or instilled clear or opaque fluid as observed by *x*-ray examination.

A complete *x*-ray study should be had immediately, providing the condition of the patient permits. A portable *x*-ray, however, is often sufficient for a preliminary study.

Fractures of localized areas of the pelvis, not involving the pelvic ring, show rather distinctive physical signs and symptoms. The more common ones, involving the spines, iliac crests, or tuberosities of the ischium show local trauma with pain, ten-

derness, crepitation, ecchymosis and local mobility. Fractures of the floor of the acetabulum may be complete or incomplete, associated with limitation of motion, with pain of the affected leg, obliteration and flatness of the natural round contour of the affected hip, depending on the degree of depression. *X*-ray will complete the diagnosis.

Fractures of the rim of the acetabulum are rather infrequent and are difficult at times to diagnose early and correctly even by *x*-ray examination. Fractures of the inferior margins are less difficult to recognize and less dangerous from the point of view of return of function. Fractures of the superior margin, however, are frequently mistaken for hip joint dislocations, due to the failure of observing the hidden and displaced fragment of the superior margin of the acetabulum. One should always suspect the latter following a history of hip joint injury upon a failure to maintain reduction of a supposed dislocation of the hip joint. Fractures of the sacrum are infrequent and in the absence of displacement present only moderate local discomfort without, as a rule, nerve injury.

A recent study of our cases since 1916 discloses some very interesting facts concerning the care and management of fracture of the pelvis. We believe that an important factor in the initial period in the treatment of such fractures begins with the first aid rendered. The balance between death and recovery frequently depends upon the ability of the attending physician to recognize immediately a surgical problem and immobilize the parts for safe transportation to a hospital for immediate care. Delay in apparently innocent and simple cases frequently has permitted shock, ileus, perivesical and urethral injuries, and infections to develop so rapidly that some cases are hopeless upon admission to the hospital.

Within the past fifteen years an organized effort among the local physicians of our own industry (Pittsburgh Coal Company) has been made to facilitate proper first aid attention at the place of injury. Patients are immediately fixed to an improvised cushioned rectangular body splint for transportation and are well protected by blankets. Such splints and other first aid equipment are available every 1000 feet throughout each mine. Upon the arrival at the entry to the mine, the patient is placed in a warm first aid room for observation. Such further temporary attention is rendered by the local physician as he may deem wise for safe transportation to the hospital. The dangerous complications which may be avoided by the institution of such methods can be readily appreciated.

Upon admission to the hospital the patient receives the immediate attention of one of our service. A careful preliminary examination is made to ascertain the nature of the injury, the degree of shock, the blood pressure and associated injuries and complications.

If the fracture proves to be of a simple character and is confined to the pelvis without complications, an *x*-ray is taken immediately without removing the patient from the carriage. He is thereafter placed cautiously upon a firm flat bed so as to reduce further trauma to a minimum. An adhesive extension, as a temporary immobilizing measure, is applied to both limbs, in a position of moderate abduction. The patient is suspended upon a hammock, cushioned with lamb's wool and controlled by weights and pulleys, so adjusted, by a spreader, as to regulate lateral compression. A pelvic support of adhesive or a canvas belt is applied according to the findings of the individual case. The patient is then observed carefully for further developments.

It has been our practice to anticipate the development of intestinal ileus. The routine orders, unless especially contraindicated, are immediately recorded as follows: The administration of cascara pills, 15 gr. t.i.d., followed by an enema, consisting of soap suds, glycerin and sodium bicarbonate; the restriction of fluids by

mouth; and sedatives at night for rest. This treatment is usually sufficient for the mild forms of ileus. In the more severe cases, particularly those which persist for more than twenty-four hours and continuously progress, we resort immediately to turpentine stupes, surgical pituitrin, physostigmine, pitressin and prostigmine, followed by enemas at the appropriate time. All fluids by mouth are restricted to avoid aggravating an already disturbed gastrointestinal tract. Dehydration and the loss of chlorides are balanced by careful intravenous and subcutaneous administration of dextrose saline solution in quantities to meet the demand. The use of the Wangensteen suction drainage apparatus for gastric and upper intestinal distention is occasionally resorted to and at times serves a valuable purpose. It has been necessary in certain cases to resort to intraspinal and paravertebral injections of novocaine. Continuous oxygen inhalation is helpful. The establishment of such prophylactic therapy for ileus has reduced this complication, within recent years, to a minimum, and as a result, there have been no fatalities from this complication since 1926.

In the more severe forms of fractures with displacement we are guided chiefly by the *x*-ray findings. Reduction and apposition of the fragments can be accomplished frequently if attempted early by gradual and gentle manipulation and traction, at times under mild anesthesia. Reduction can then be maintained by adequate fixation.

The complications of fractures of the pelvis, as well as the concomitant injuries, are usually severe. They play an important rôle in the high mortality rate and constitute emergency surgical problems, demanding the immediate attention of an experienced surgeon. Delay and inexperience are attended by tragic results.

The most frequent and important complications, which merit a brief discussion, are: shock, ileus, hemorrhage, rupture of the rectum, urogenital injuries and infections.

Shock is one of the primary and major complications in all fractures of the pelvis. This factor comprises the highest figure in the actual cause of death in this series—45.7 per cent. Shock in simple uncomplicated pelvic fractures does exist, but it is usually mild and responds rapidly under treatment. When it occurs in a severe form, it is usually associated with grave complications or concomitant injuries, such as crushes of the thigh, vertebrae, chest, etc. We are ever mindful of this condition and attempt to establish the degree of shock upon first observation. The patient is handled with the utmost care and is immediately placed in bed under intensive treatment. Upon recovery, the patient is given further surgical care without delay.

Ileus, which was discussed above, was noted in various degrees in the majority of cases. Certain patients presented a delayed form of ileus, which appeared two to four days after injury. This type may become extremely severe and very embarrassing to the patient. Occasionally, a recurrent form appears, demanding return to the primary treatment. A wide review of the literature shows but little reference to ileus as an important complication and practically no mention is made of its mechanism of development as the result of trauma. Irritation of the autonomic nervous mechanism is a major factor in the induction of ileus. In this series 22.7 per cent of the deaths resulted from it.

Injuries to the urogenital tract constitute the chief surgical complication. In such cases, success or failure depends upon the time of recognition. If extravasation of blood and urine in the traumatized pelvic tissues continues for more than six or eight hours without detection, a chemical cellulitis develops with a subsequent bacterial invasion, resulting in a fulminating infection and extreme toxemia. Ascending kidney infection may arise following acute retention. Peritonitis develops rapidly in delayed conditions of intraperitoneal rupture of the bladder. These complications can be avoided by early recognition and

the proper institution of surgical measures if the problem of shock does not interfere.

The appearance of blood at the urethral orifice is sufficient warning of mucosal damage. Investigation by catheter is performed under strict asepsis and with caution to avoid further trauma. If simple laceration exists, with little or no periurethral or perineal extravasation, an indwelling catheter, introduced into the bladder, is usually sufficient treatment, with subsequent repair of the urethral lumen.

If obstruction is encountered, a retrograde catheterization, with suprapubic cystostomy, is our method of choice for repair of the ruptured urethra. The suprapubic incision into the bladder is made high so as to avoid a permanent urinary fistula. Care should be exercised to avoid incising the peritoneum. The urethral catheter, which extends throughout the entire channel from penis to suprapubic opening, is not fenestrated for drainge of urine but serves as a scaffold for the restoration of the urethra. Complete through and through drainage of the space of Retzius, from the suprapubic incision through an incised wound in the midperineal line immediately below the scrotum, is thoroughly established to avoid infection of the pelvic tissues. The bladder is drained independently by the introduction of a Petzer catheter, through the suprapubic opening, so as to relieve urethral tenesmus and avoid soiling of the surrounding surface of the suprapubic wound. The drainage in the space of Retzius is retained from eight to fourteen days. The urethral catheter may be safely removed in two or three weeks. A silk guide suture is left throughout the urethral canal and bladder, which facilitates the subsequent introduction of sounds. Following the reëstablishment of urethral function, the suprapubic opening heals rapidly. The periodic passage of sounds, to avoid stricture, is highly essential at a later date. It is impossible to over-emphasize the importance of aseptic technique in this procedure to guard against the development of infection. Indeed, the preliminary catheterization of patients with suspected urethral damage should be performed with strict aseptic precautions.

The first laparotomy for the repair of a rupture of the bladder was performed in Pittsburgh on January 12, 1859, by Dr. Albert G. Walter, who reported the case in the *Medical and Surgical Reporter* of Philadelphia, November 16, 1861. Dr. Robert W. Stewart, formerly Professor of Surgery at the University of Pittsburgh, did much to popularize and improve the technique of the retrograde catheterization method.

Extraperitoneal rupture of the bladder is approached and repaired by a suprapubic cystostomy with adequate drainage. The removal or replacement of protruding sharp spicules within the bladder is often necessary and should be done cautiously before the ruptured area is closed. Suprapubic and sometimes extravesical drainage is necessary.

Intraperitoneal rupture of the bladder requires, as a matter of safety, a preliminary laparotomy for removal of the free urine. The surgical repair of the lacerated bladder may be accomplished either by intraperitoneal approach or during the routine suprapubic cystostomy for drainage. If the peritoneal involvement is extensive, drainage is established and other surgical measures for similar peritoneal insults.

These cases require careful postoperative care in order that local, as well as ascending kidney infection, may be avoided. The individual should return monthly during the following year in order that patency of the urethra may be maintained and the development of stricture prevented.

The occurrence of vesical calculi following these injuries is occasionally disturbing and should receive early attention. However, this condition frequently can be avoided by careful attention to the bladder during the postoperative period. However, the bladder seldom requires care unless gross infection has occurred.

Injury to the rectum should not be overlooked. A routine examination may show the presence of sharp fragments which occasionally protrude through the rectal wall. Gentle finger pressure is often sufficient to reduce the fragment a safe distance. Occasionally complete rupture of the rectal mucosa results from the sharp spicules, and this of course requires repair. Damage to the rectum frequently offers a portal of entry for the invasion of organisms into the soft perineal tissues. The development of gas bacillus infection is a not infrequent finding which is usually fatal if not recognized early.

Pertaining to the convalescent care of the pelvis and the adjoining soft structures, it is essential to immobilize the pelvis with properly applied extensions. In simpler forms, showing only a moderate degree of displacement, a Buck's extension is applied with a preliminary application of 30 pounds weight, and the limbs are maintained in a posture of approximately 15 degrees abduction in order to avoid contracture of the adductor muscles. Where the *x*-ray findings point to a marked deformity, with distortion and displacement of the fragments, as in the vertical type, or sacroiliac separation with displacement, and where reduction cannot be obtained by gentle traction and manipulation, a skeletal traction apparatus, such as the Anderson outfit, has been very useful in several of our cases. Open reduction in these cases is not only unnecessary but quite dangerous and impracticable. With certain modifications, the hammock suspension, as originally introduced by Conwell, has proved ideal for comfort, sanitation, and protection. It facilitates the moving of the patient about the bed with safety. The hammock, I believe, has proved to date the most valuable agent in the general treatment of fractures of the pelvis, except in certain specific instances, where additional methods are necessary.

All patients, except those with very minor fractures, such as simple fractures of the ilium, are confined to bed at total rest for a period of eight or ten weeks, following which the patient is confined to a wheel chair for a period of two weeks before the body weight is superimposed upon the pelvis in the erect position.

Physical therapy, including infra-red rays, massage, interrupted galvanism and diathermy, is instituted the first or second week following admission. This is continued throughout the confinement of the patient in the hospital.

Complete *x*-ray studies, in various postural positions, are essential to determine the progress of reduction, the development of unusual deformities and the condition of the pelvic structure upon the discharge of the patient. There are certain other sequelae of fractures of the pelvis which deserve consideration.

Malunion of the fractured bones of the pelvis, with deformation and deficiencies of locomotion and support do occur, but rather infrequently. It is surprising at times, that despite the presence of malunion, excellent return of industrial function occurs in certain of these cases. At times sufficient firm fibrous union occurs with total absence of one side of the pubic bone, yet, the counter arch is so firmly united by fibrous union, as to permit the patient to engage in the work of a miner with fair earning capacity.

In two patients, marked separation of the symphysis with fracture and displacement of both sacroiliac joints persisted. Our inability to effect reduction at the time of injury was occasioned by a severe gas bacillus infection and other injuries. A recovery from the infections resulted in both cases, but a total loss of lifting power and improper balance and locomotion persisted. The counter or subsidiary arch was effectively tied at a later date by a subsequent bone graft, which still remains viable, in the first case for seven years and in the other for three years. Complete restoration of strength and function was afforded to the pelvic structure.

Urethritis cystitis, prostatitis, seminal vesiculitis, pyelonephritis and pyonephro-

sis, which result from ascending infection and which frequently prove serious, can often be avoided by early operation and adequate drainage. The treatment of these cases, however, demands the attention of one well trained in genitourinary problems.

In our experience, persistent urinary fistula has never occurred in any cases of urogenital complications repaired by the retrograde catheterization method. The bladder incision should always be made high in the fundus of the bladder in order to avoid a urinary fistula.

Adductor disabilities can be greatly reduced by maintaining the lower limbs in a position of abduction during confinement to bed, assisted by physical therapy.

Foot drop, which occurred in two cases of this series, may assume the proportions of a permanent disability. Fixation of the foot in dorsal flexion with a removable splint, accompanied by infra-red treatment and massage during confinement to bed, the subsequent wearing of a specially devised shoe, with an attached traction apparatus, and continued physical therapy when the patient is ambulatory, have resulted in very favorable results.

Lumbar myalgia at times is persistent and difficult to obviate, yet the number of these cases has been consistently reduced following the practice of total confinement to bed for eight weeks or longer.

Impotency represents a sequela which should not be overlooked. It is infrequent in our experience, occurring chiefly in those cases associated with ruptured urethra and periurethral damage. Delayed function occurred in two cases. Abbott in his discussion on ruptured urethra is one of the few who attempts an explanation. He attributes the condition to a tearing of the greater and lesser cavernous nerves which supply the corpora cavernosa.

Fractures of the superior margin of the acetabulum with associated dislocation of the head of the femur are rare and are disabling if not corrected. In three of this series an associated dislocation of the femoral head occurred in addition to displacement of the superior acetabular fragment. One was reduced by a lateral exposure, the other two by the Smith-Peterson approach, which simplified the operative technique considerably. In all three cases, there was a full return of function of the hip joint. Fractures of the inferior margin, the fragments of which are seldom grossly displaced, usually do very well by total rest and immobilization by the extension method.

A review of our mortality list keeps us ever mindful of the interest and desire for future improvement in the care and management of these cases. A number of the patients who died, and who are included in this series, succumbed shortly following admission. As a matter of record and study we feel they should all be included.

Total number of cases treated since 1916.....	255
Average days of disability	144.3
Total number of deaths..	35
Percentage of deaths.....	13.7 per cent

The causes of death were as follows:

	Number	Per Cent
Shock	16	45.7
Ileus	8	22.7
Pelvic cellulitis plus one gas bacillus	4	11.4
Ascending urinary infection	3	8.5
Cardiac failure	2	5.7
Meningitis	1	2.8
Hemorrhage	1	2.8
Total	35	100

COMMENT

1. Fractures of the pelvis are major surgical problems and should be treated in the hospital.

2. The treatment has its origin with the first aid established.

3. Sufficient period of immobilization at total rest with early physical therapy will prevent or reduce permanent disabilities.

4. Complications should be regarded as emergencies.

5. Early recognition by the physician and surgeon is most essential.

6. An experienced surgeon should assume personal care of all complications.

7. A review of our work of fractures of the pelvis keeps us ever mindful of the importance of a sincere effort to bring about good alignment and good apposition of the fragments as a means of reëstablishing a restoration of function.

REFERENCES

Quain, E. P. Ruptured bladder associated with fracture of pelvis. *Surg., Gynec. & Obst.*, July 1916.

Abbott, A. C. Rupture of urethra associated with fracture of pelvis. *Canad. M. A. J.*, 20: 634–637 (Jan.) 1929.

Noland, L., and Conwell, H. E. Fracture of pelvis. *Surg., Gynec. & Obst.*, 521: 525, 1933.

Jones, R. W. Dislocations and fracture dislocations. *Brit. J. Surg.*, 25: 773–781 (April) 1938.

Callahan, J. J. Fractures of pelvis. *Indus. Med.*, 6: 651–654 (Dec.) 1937.

Eliason, E. L., and Johnson, J. Fractures of the pelvis. *S. Clin. North America*, 17: 1571–1584 (Dec.) 1937.

Carruthers, F. W. Anatomic and functional results in fracture of the pelvis. *South. M. J.*, 31: 451–453 (April) 1938.

Noland, Lloyd. Late sequelae from medicolegal point of view, cases. *Am. J. Surg.*, 38: 608–611 (Dec.) 1937.

Rankin, L. M. Fractures of the pelvis-review of 449 cases. *Ann. Surg.*, 106: 266–277 (Aug.) 1937.

Lam, C. R. Nerve injury in fractures of pelvis. *Ann. Surg.*, 104: 945–951 (Nov.) 1936.

Stern, W. G. Fracture dislocation of sacro-iliac joint reduced by well leg traction method. *Am. J. Surg.*, 32: 179 (April) 1936.

Conway, F. W. Fractures of the pelvis. Clinical study of 56 cases. *Am. J. Surg.*, 30: 69–82 (Oct.) 1935.

Langan, A. J. Use of Jones splint in treatment of fracture of pelvis and neck of femur. Series of 40 cases. *J. Bone & Joint Surg.*, 17: 435–442 (April) 1935.

Wakeley, Cecil P. G. Fracture of the pelvis, an analysis of 100 cases. *Brit. M. J.*, 17: 65 (Nov.) 1929.

Westerhorn, A. Fractures and dislocations of the pelvis. *Acta chir. scandinav.*, 63, Supp. viii, 1928.

FRACTURES OF THE UPPER END OF THE FEMUR INCLUDING FRACTURE DISLOCATIONS AT THE HIP JOINT

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INTRODUCTION

THE unusually heavy musculature and soft part surrounding the hip joint have made the above fractures one of our most difficult problems. In view of the rapid march of time it would seem that only yesterday many of these fractures were considered to be utterly hopeless and their unfortunate victims were relegated to the list of permanent invalidism and in many instances to early death. Today our viewpoint has changed considerably. Pessimism and hopelessness have given way to optimism and hope. To what do we owe this seemingly great medical triumph?

Cordasco in his recent publication in the *Archives of Surgery* entitled "Evolution of Treatment of Fractures of the Neck of the Femur" gives an excellent chronological and historical survey leading up to the present era of progress. The innumerable contributions which he lists have all played a distinct and invaluable part in the handling of this most interesting division of medicine. Were one to select the outstanding contributions essential to this progress, the selection would indeed be difficult. Perhaps we might start with crediting Ambroise Paré as the first to recognize and report a case of fracture of the neck of the femur. Heister and Ruysch later described the pathologic appearance of this fracture as it appeared at autopsy. Sir Astley Cooper was among the first to distinguish between intracapsular and extracapsular fractures, and he pointed out the unfavorable prognosis of the former and the favorable prognosis of the latter. To Roentgen we owe gratitude and honor for his discovery of the *x*-ray. His contribution is the most important of all. The actual visualization of these fractures has made it possible not only to correctly diagnose them but to classify them intelligently from the standpoint of treatment and prognosis. To Royal Whitman we must credit the first excellent method of reduction and fixation. Whitman stressed most energetically the importance of both the intracapsular and the extracapsular fractures. His method became a boon to thousands of aged individuals who were treated by supportive measures existing prior to his time and who had only the prospect of invalidism. To Albee we owe the credit for the autogenous bone peg employed as an internal fixation method for fractures of the neck of the femur. Albee's contribution marked a very definite advancement in the treatment of non-united fractures of the neck of the femur. To Kolodny and Wolcott we owe a most generous consideration for their valuable contribution concerning the blood supply to the upper end of the femur. And, finally, to Smith-Petersen we must give credit for establishing a method of internal fixation for fractures of the neck of the femur which has supplanted all previous methods and is primarily responsible for our present day success. Through the development of his three-flanged nail for the purpose of internal fixation the most remarkable progress has occurred. First of all it has brought to our attention the necessity of an accurate reduction. The radiologists, through Johnson, George, and Leonard, have met this challenge by improving the *x*-ray technique in taking lateral views of the acetabulum, the head, the neck, and the trochanteric

areas of the femur. Improvements upon the reduction methods of Whitman have been offered by Leadbetter, Snodgrass, and others. In addition, the percentage of union in fractures of the neck of the femur has increased and the mortality rate has been materially lowered.

To Hoke, Jones, and Anderson one must credit the well leg traction principle and its development which has offered us a distinct advancement in the treatment of extracapsular fractures. In view of the interest attending the successful progress made in fractures of the neck of the femur, the extracapsular fractures have fallen somewhat into obscurity. They remain nevertheless extremely important problems, particularly in view of their frequency and of the disability so often due to inadequate reduction.

Fractures of the greater and lesser trochanters, and fracture dislocations at the hip, including the posterior and the central types, have received comparatively scant attention. This apparent negligence is due primarily to their relative infrequency, and secondarily, to the consummation of the time and energy devoted to femoral neck fractures.

It is obvious that the foregoing introduction merely touches on some of the highlights associated with the progress related to this important group of fractures.

The remainder of this section will be devoted to the classification, illustration, and a brief description of each fracture with special reference to diagnosis, treatment and prognosis.

CLASSIFICATION

1. Fractures of the upper end of the femur
   - A. Fractures of the femoral head
   - B. Fractures of the neck of the femur
     1. Subcapital
     2. Cervical
     3. Basilar
     4. Slipped femoral epiphysis
   - C. Trochanteric fractures
     1. Trochanter major
     2. Trochanter minor
     3. Intertrochanteric
     4. Pertrochanteric
     5. Subtrochanteric
2. Fracture dislocations at the hip joint
   - A. Central dislocation of the femoral head
     1. Pure central dislocations (fracture limited primarily to the acetabulum, its rim and wall)
     2. Central dislocations involving the rim, the floor, and the lateral wall of the pelvis (ischium valgum)
   - B. Posterior dislocation of the femoral head accompanied by fracture of the acetabular rim
   - C. Posterior dislocation of the acetabulum accompanied by fracture of the femoral head

DISCUSSION

1. *Capital Fractures.* (Figs. 1, 3, 4, and 5.)
   - A. Etiology. Direct violence applied to the head of the femur through the thigh with the thigh in the semiflexed and adducted position.
   - B. Types. (1) A fracture of the femoral head accompanied by a subcapital fracture (Fig. 5); (2) a fracture of the femoral head accompanied by posterior superior hip joint dislocation. (Fig. 4.)
   - C. Signs and Symptoms. (1) The thigh is adducted and flexed—the amount depending upon the degree of dislocation present. (2) Muscle spasm, pain, and crepitus are present at the hip joint. (3) Movement is restricted in all directions.
   - D. Diagnosis. It is suspected from the above signs and symptoms but is established only by the *x*-ray.
   - E. Differential Diagnosis. (1) Pos-

terior superior dislocation; (2) subcapital fracture; (3) fracture of the neck and trochanteric

Should the blood supply from this source prove inadequate, one might expect delayed union or more probably nonunion.

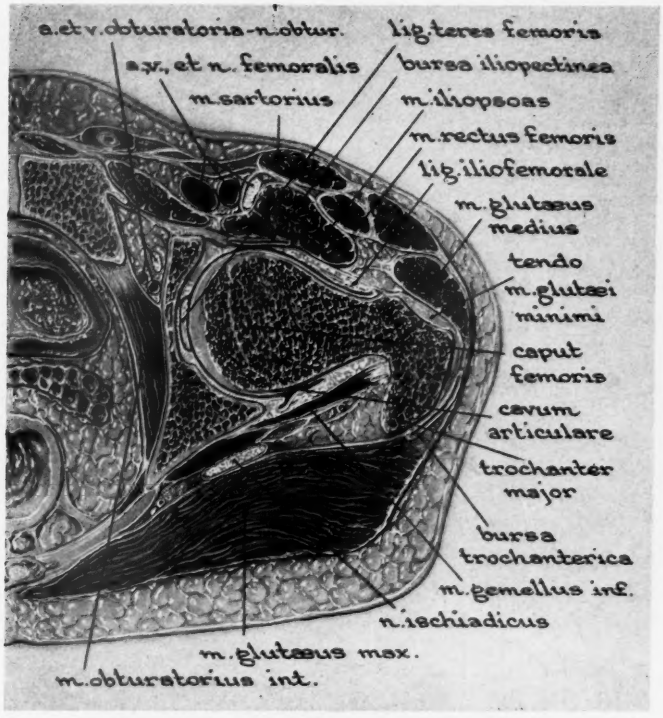


Fig. 1. A cross section of the human pelvis at the level of the femoral neck (Eycleshymer and Schoemaker).

areas. The diagnosis is established primarily by the *x*-ray.

F. Treatment. (1) Type 1 requires excision of the femoral head fragments and one of the reconstruction operations. (2) In Type 2 one may use: (a) reduction as if it were a posterior superior dislocation; (b) plaster immobilization for eight weeks; (c) non-weight-bearing walking caliper for six months; (d) physiotherapy.

G. Prognosis. In Type 1 very poor; in Type 2 good.

Figure 4A illustrates a three year end result in the case shown in Figure 4. Solid union and excellent hip joint movement are present.

Note. Capital fractures are intracapsular fractures. The circulation of one or more fragments may be dependent solely upon the ligamentum teres for blood supply.

2. *Fractures of the Neck of the Femur.*

A. *Subcapital* (Figs. 1, 3, 5, and 6.)

1. Etiology. The mechanics of the fracture production is probably similar to that occurring in capital fractures. The thigh is in less adduction and the neck is literally sheared off the head at the border of the acetabular rim. (Fig. 6.) A capital fracture may occur in conjunction with the subcapital fracture. (Fig. 5.)

2. Physical Signs. The signs and symptoms are similar to those which are observed in cervical fractures. (See cervical fractures). The *x*-ray demonstrates a fracture of the femoral neck at the base of the head. The fracture line corresponds approximately to the

site of the former epiphyseal line.

3. Diagnosis. There are no clinical signs specific for this fracture. The detection is dependent entirely upon the *x*-ray.

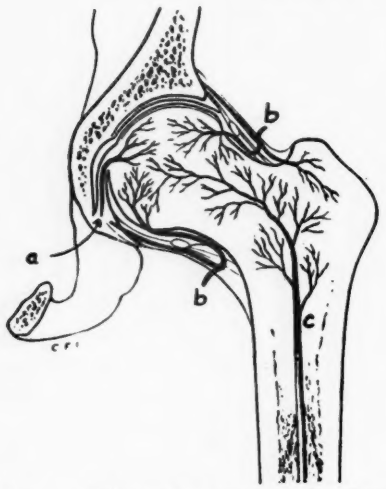


Fig. 2. Schematic drawing showing the circulation of the head and neck of the femur (Campbell). *a*, artery of the ligamentum teres. *b*, capsular arteries. *c*, nutrient artery.

4. Differential Diagnosis. This fracture must be differentiated particularly from the cervical and capital fractures. (See prognosis). The distinction is determined radiographically.

5. Treatment. The treatment is similar to that of cervical fractures with this modification—complete bed rest with weight and pulley traction for twelve weeks. Partial weight bearing—caliper and crutches—for six months. (See treatment of cervical fractures).

6. Prognosis. The prognosis is poor due to: (1) the circulation of the proximal fragment is dependent entirely upon the ligamentum teres for its blood supply. The blood supply of the ligamentum teres is inadequate in the majority of cases. (Fig. 2.) The subsequent displacement after excellent reduction is very apt to occur in view of the fact that the fracture line is constantly subject to a shearing stress. Accurate reduction is absolutely essential. Coxa vara must not be accepted. Coxa valga, though more favorable, diminishes the amount of fracture surface apposition. Internal fixation is essential to maintenance.

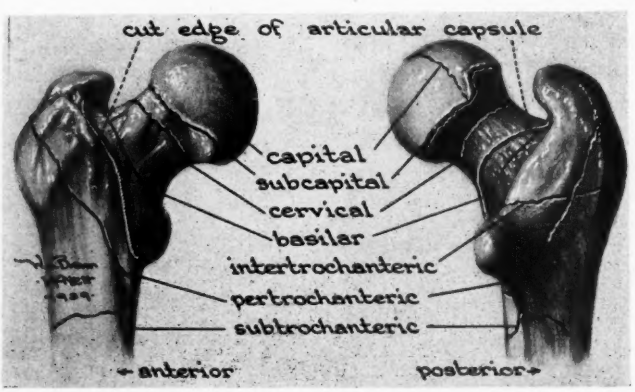


Fig. 3. An anterior posterior view of the proximal end of the femur. Note the various fracture planes and their relationship to the capsule attachment.

Note. It is extremely important that the subcapital fracture be not carelessly included in the cervical fracture group. It should be given special consideration in

view of the fact that it ranks first in nonunion of all fractures of the femoral neck.

A B

Fig. 4. A, a capital fracture. One-half of the femoral head remains in the acetabulum. The other half is dislocated and remains attached to the femoral neck. B, fracture healed.

B. *Cervical* (Figs. 1, 3, 7, and 8.)

1. Etiology. Cervical fractures are commonly known as fractures of the aged, and are most frequently seen in the fifth, sixth, seventh, and eighth decades of life. They are produced by indirect violence. The patient usually has a fall, striking on the posterolateral aspect of the hip. The thigh is flexed, adducted, and internally rotated. The force is spent largely on the trochanter and in the direction of internal rotation. The mechanism of the fracture is essentially one of internal torsion.
2. Physical Signs. The extremity is externally rotated (helpless eversion), slightly adducted, and various degrees of shortening are present, depending upon the amount of displacement present. The trochanter is above Nelaton's line. Bryant's triangle is obliterated. Crepitus and muscle spasm are noted. Movement is restricted in all directions (pseudoparalysis). There is marked local tenderness over the anterior aspect of the hip joint, just lateral to the femoral artery. The patient is usually in moderate shock and generally complains of intense pain in the hip joint, sometimes referred to the knee.
3. Differential Diagnosis. Cervical fracture must be differentiated from the trochanteric and subcapital fractures. The *x*-ray is absolutely necessary for this distinction.
4. Diagnosis. The diagnosis is based primarily on the *x*-ray signs.
5. Treatment. Reduction—The *x*-ray clearly defines the frac-

ture deformity. Simple stero anteroposterior views are inadequate for this purpose.

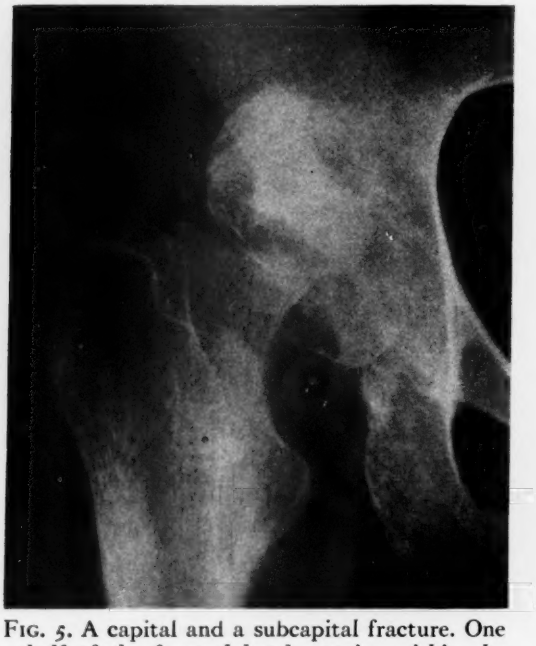


FIG. 5. A capital and a subcapital fracture. One half of the femoral head remains within the acetabulum while the other half is displaced superiorly. The neck is separated from the head fragments by a fracture through the subcapital area.

The anteroposterior and the lateral views are essential to this determination. (Fig. 7.) The essentials of fracture deformity are: (a) shortening; (b) external rotation of the distal fragment; (c) anterior or posterior displacement of the distal fragment; and (d) coxa vara. Normally the neck and shaft form an angle of approximately 125 degrees. In cervical fractures this angle approximates 90 degrees or less.

To reduce the fracture one must eliminate the above deformity factors. The essentials to reduction are: (a) traction (b) internal rotation; and (c) abduction. These movements must be simultaneous, for one done independently tends to prevent the completion of the other two movements. The Leadbetter or the Whitman maneuver is usually employed for reduction. Both procedures are dependent primarily on the above principles. In the Whitman method

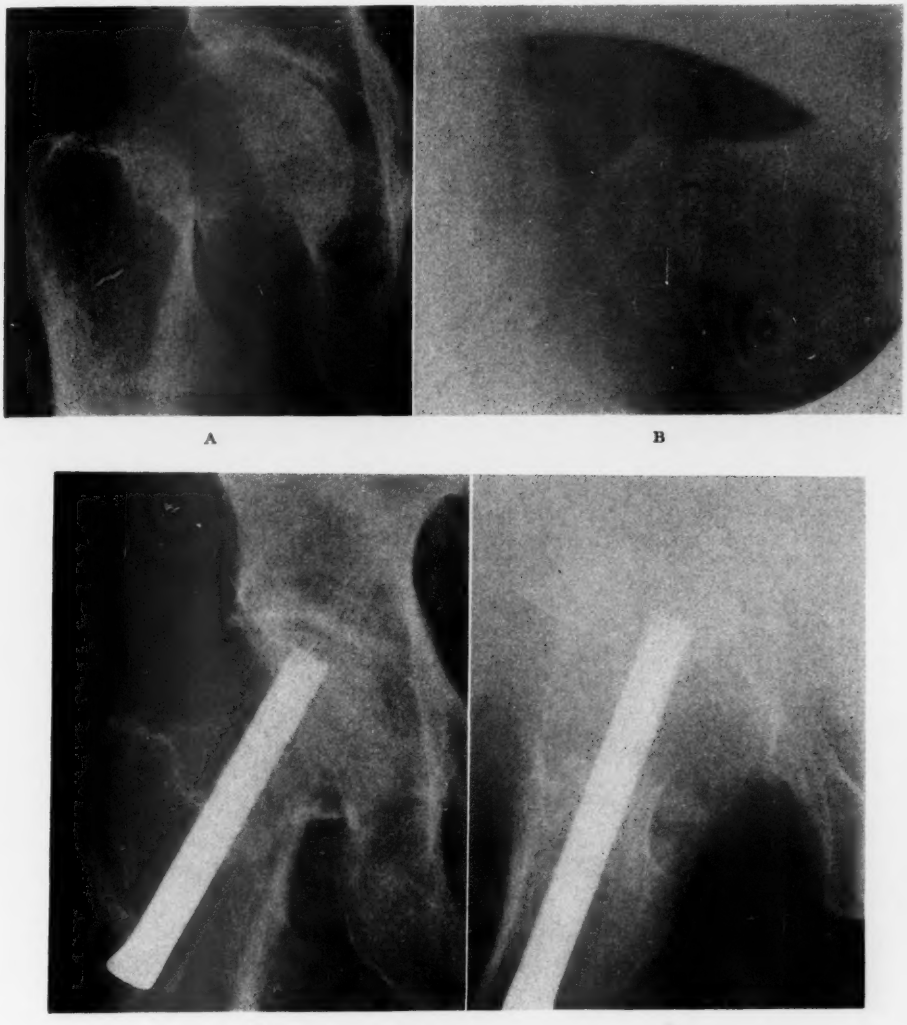
FIG. 6. A subcapital fracture.

the correction is executed with the thigh in the horizontal position. Leadbetter performs the identical correction with the thigh and knee flexed 90 degrees. He contends that the joint structures are more relaxed in this position, thus facilitating reduction.

Reduction Test. There is but one reliable reduction test and this is the *x*-ray. After the reduction maneuvers have been executed, the corrected position is maintained by keeping the thigh abducted, internally rotated, and in moderate hyperextension. The "Y" ligament of Bigelow, according to Royal Whitman, is placed under extreme tension while the extremity is in this position, and this rugged, powerful ligament is thus capable of maintaining the fracture surfaces in apposition. The anteroposterior and lateral *x*-rays must then be repeated.

Leadbetter has described the heel and palm test (Leadbetter's sign) as a valuable means of determining a successful reduction. The test briefly is as follows: After his

reduction maneuver, the thigh is placed in abduction, internal rotation, and hyperextension to maintain reduction. The heel of the normal side in the palm and does not maintain forced abduction, the extremity immediately rolls into external rotation. If



A B C D

Fig. 7. A, anterior-posterior view of a cervical fracture. B, lateral view. C, the fracture reduced and fixated by the Smith-Petersen nail. A. P. view. D, lateral view.

on the fractured side is then allowed to rest on the palm of the hand. If the extremity rolls outward (externally rotates) reduction has failed. If, on the other hand, the extremity remains internally rotated, the reduction is complete.

Note. The writer is not in accord with the Leadbetter reduction sign for the following reason: Continuous abduction must be maintained even on the normal side in order to prevent the extremity from externally rotating. If one places the heel sufficient abduction is maintained on the side of an unreduced fracture, the thigh will not externally rotate. The test, therefore, from the writer's viewpoint, is of questionable value.

Fixation. Internal fixation is maintained by means of the Smith-Petersen nail. Fixation may be obtained by nail, pins, wire, screws, autogenous bone graft, or other materials. The three-flanged nail of M. N. Smith-Petersen and the steel pin of Austin Moore are probably the most widely

used agents at the present time. Blind nailing or pinning has almost entirely supplanted the open reduction methods.

A B

Fig. 8. A, a non-united cervical fracture. The neck of the femur has undergone absorption. The head is dead. Note especially the increased density of the head compared to the density of the surrounding bone. B, same fracture two years after a Brackett reconstruction operation.

Blind nailing is accomplished either by the wire guide, one of the numerous direction finders, or by means of the fluoroscope. The writer prefers the Smith-Petersen nail and employs the fluoroscope for its insertion. An incision only large enough to admit the nail is made at the base of the great trochanter.

The exact site is determined with fluoroscopic guidance. The nail is then directed through the central portion of the neck into the center of the head—with the aid of the fluoroscope. It is necessary repeatedly to check the course of the nail in the anteroposterior and the lateral views. Should visualization become doubtful, anteroposterior and lateral *x*-rays are taken. In case the alignment is unsatisfactory, the nail is retracted and reinserted. Regardless of the method of nailing, or the material used, the following essentials are necessary to adequate internal fixation: (1) pre-reduction visualization with anteroposterior and lateral *x*-rays (Fig. 7A and B); (2) accurate reduction; (3) a centrally positioned nail or properly placed wires or pins (Fig. 7C and D); (4) impaction of the fragments if there is the slightest evidence of distraction; and (5) adequate anteroposterior and lateral post-reduction films (Fig. 7C and D).

Note. Adequate anesthesia, preferably general, eliminates one of the principal reduction obstacles. Complete relaxation is essential to the reduction of any fracture. Many fracture methods have been devised and thought necessary because of the violation of this principle. Avertin anesthesia supplemented by nitrous oxide has proved satisfactory to the writer.

Post-Reduction Care. (1) Bed rest with weight and pulley for eight weeks. (2) Anteroposterior and lateral *x*-rays at the end of six weeks. (3) Crutches with partial weight bearing for six months. (4) Anteroposterior and lateral *x*-rays at the end of six months.

Note. Physiotherapy during the entire protection period directed principally to the maintenance of proper muscle tone about the hip and knee is necessary.

Prognosis. The prognosis is dependent upon the following factors: (1) accurate reduction; (2) adequate fixation; (3) ade-

quate after-care; and (4) blood supply to the proximal fragment.

Since the establishment of internal fixation by Smith-Petersen in 1925, the percentage of osseous union in cervical fractures of the femur has constantly risen. A successful result may be expected in approximately 75 per cent of the cases of cervical fractures according to reports of the majority of fracture clinics. The blood supply of the proximal fragment is still a problem of controversy. The femoral head and neck receive their blood supply from four sources (Fig. 2): (1) nutrient artery; (2) superior capsular vessels; (3) inferior capsular vessels; and (4) ligamentum teres.

Fig. 9. A, a basilar fracture. The fracture line extends partly into the great trochanter. Hence, it is not a true basilar fracture. B, anteroposterior view of the same fracture shows the fracture confined primarily to the base of the neck. C, anterior-posterior view of the nailed and healed fracture. D, lateral view.

In subcapital and high cervical fractures in which there has been extensive displacement the proximal fragment may depend entirely upon the ligamentum teres for its blood supply. The capsular vessels enter

the neck at its base and in the above types the blood supply to the proximal fragment is cut off. The ligamentum teres may afford

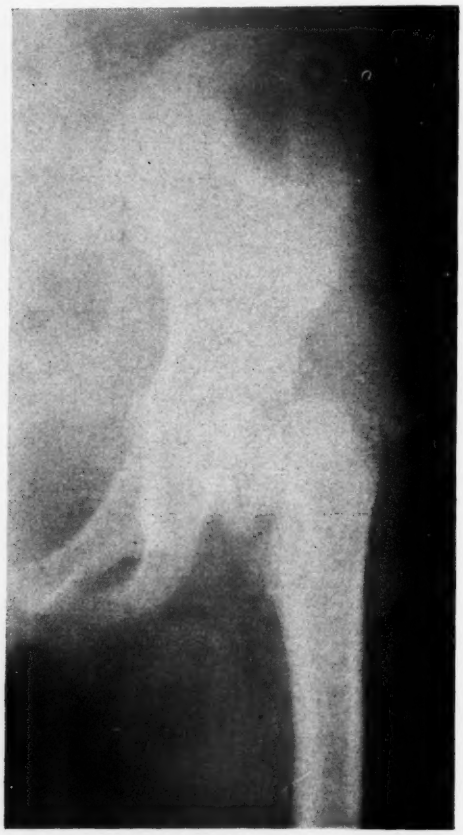


Fig. 10. Anteroposterior view of a slipped femoral epiphysis.

an inadequate blood supply. The proximal fragment may therefore die. The death of this fragment is referred to as "the aseptic necrosis of Phemister." (Fig. 8A.) Non-union occurs. In these cases one of the reconstruction operations, as that of Brackett, Whitman, Albee, Colonna, etc., may be necessary to eliminate pain and to restore some degree of usefulness to the hip. The writer prefers the Brackett operation. (Fig. 8B.) Non-union may also occur here, in fact does frequently occur, because of improper reduction or improper fixation. In many of these cases the head remains viable. The Albee bone graft is the method of preference in this group.

The prognosis in the cervical fracture has a far brighter outlook than ever before. The Whitman abduction cast method has apparently served its usefulness and has been replaced by internal fixation. The convalescent period is more comfortable and the mortality rate of the cervical fracture has been materially lowered. Smith-Petersen and others have stressed the importance of a two year follow-up before coming to a final decision regarding bony union. This may greatly reduce the present optimism. But, even so, in view of the foregoing statements relative to the advantages of internal fixation, the method will have earned its right to exist.

Note. Recognition of the "dead head" is determined by the *x*-ray—principally. (Fig. 8A.) It is characterized by its intense whiteness in comparison with the surrounding bony structures. The increased density is thought to be due to a total loss of blood supply. Demineralization due to disuse occurs in all bony structures, but can occur only providing an intact blood supply is maintained.

Caution: Non-union due to poor reduction, poor fixation, and in general poor treatment is too frequently attributed to the dead head. For that reason one must take care not to overemphasize this interesting but very infrequent complication.

C. *Basilar.*

The previous fractures have been intracapsular. The basilar fracture has the unique distinction of being intra- and extracapsular. (Fig. 3.)

Etiology. Indirect force similar to that producing trochanteric fractures.

Physical Signs. Similar to cervical fractures.

Differential Diagnosis. *X*-ray.

Diagnosis. *X*-ray.

Treatment. Identical with that for cervical fractures—internal fixation.

Prognosis. Excellent.

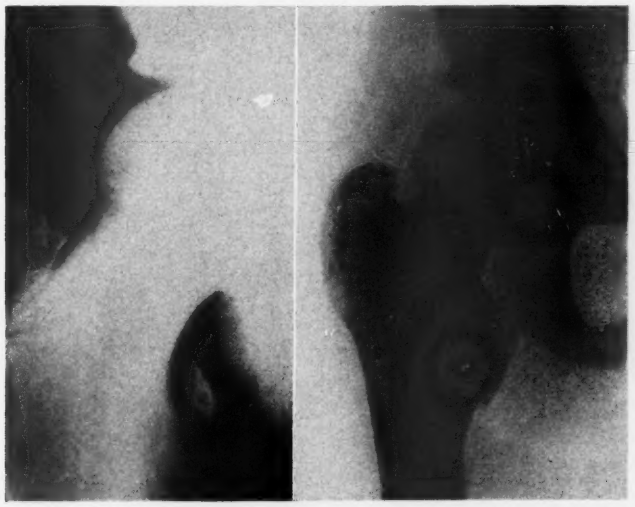
Note. The proximal fragment is assured of a blood supply. The large diameter of the cervical base affords broad contact.

D. *Slipped Epiphysis.*

The slipped epiphysis belongs probably to the pathologic fractures of the neck of the femur. It occurs more frequently in

females than in males and is usually seen between the ages of 12 and 18 years.

Etiology. The slipping progresses rather slowly until some comparatively minor injury produces a sudden and marked displacement. The displacement or slipping occurs at the epiphyseal line, and the location corresponds to the subcapital fracture seen in the adult. The frequency with which the slipped epiphysis is seen in the hypopituitary type suggests an endocrine basis for its occurrence. The failure of the early cases to respond to endocrine therapy has been very discouraging and has cast grave doubt upon this explanation.



A B

Fig. 11. A, fracture of the trochanter minor. B, healed fracture. (Courtesy of J. T. Nicholson.)

Clinical Signs. The obese adolescent girl (Fröhlich type) begins to limp slightly. The hip gradually becomes stiff and the extremity becomes shortened. Pain is usually present at the hip but very often present only at the knee joint (referred pain). If the joint movement is determined at this period, there is found a loss of abduction, internal rotation and extension. A slight misstep or trivial fall suddenly produces a sharp pain at the hip joint. The *x*-ray shows the femoral head in the acetab-

A B

Fig. 12. A, pertrochanteric fracture—simple. B, pertrochanteric fracture—comminuted.

ulum. The neck is displaced upwards. The distal fragment is in marked external rotation, and coxa vara is noticeable.

In the pre-slipped period it is often confused with coxa plana and epiphysitis of low grade inflammatory origin. Prolonged observation is frequently necessary in these more difficult diagnostic cases.

Fig. 13. Intertrochanteric fracture.

Fig. 14. Subtrochanteric fracture.

Diagnosis. The diagnosis is suspected in view of the clinical signs and is corroborated by the *x*-ray. The lesion is very often bilateral. The stages of slipped epiphysis are recognized by:

1. Pre-slipped period. The epiphyseal line is widened and irregular. The adjacent neck is widened, particularly the inferior surface. This latter projects below the head and looks somewhat like a chin. The deformity is referred to as "chinning." At this stage one may notice a slight bending of the neck in the anteroposterior view. This bending occurs at the junction of the neck and epyphyseal line (metaphyseal area). In the lateral view a slight but very definite anterior bending may be present.
2. Slipped period. Described under the physical signs.

Differential Diagnosis. This condition must be distinguished primarily from subcapital fracture. The *x*-ray and clinical pictures make the diagnosis relatively easy.

Treatment.

1. Pre-slipped period. Internal fixation with the Smith-Petersen nail offers the most certain means of arresting the process.
2. Slipped period. One may divide the cases into two groups. (a) Fresh slipped—reduction is accomplished similar to that in cervical fractures but with utmost gentleness, followed by immediate internal fixation; (b) Older cases with malunion —subtrochanteric osteotomy offers the most helpful outlook.

Prognosis. Excellent in the preslipped period; good in the fresh slipped group and rather poor in the malunited group. (Fig. 10.)

3. *Trochanteric Fractures.*

A. *Trochanter Major.* This is a very rare fracture. It is produced by direct force.

Physical Signs. The thigh is adducted. Active abduction of

the hip is lost. External rotation and extension (active) are greatly diminished. Marked local tenderness over the lateral aspect of the hip is present. Crepitus may be noticed upon palpation of the greater trochanter. A mass can frequently be felt. Extensive ecchymosis is seen over the lateral and posterior area of the hip.

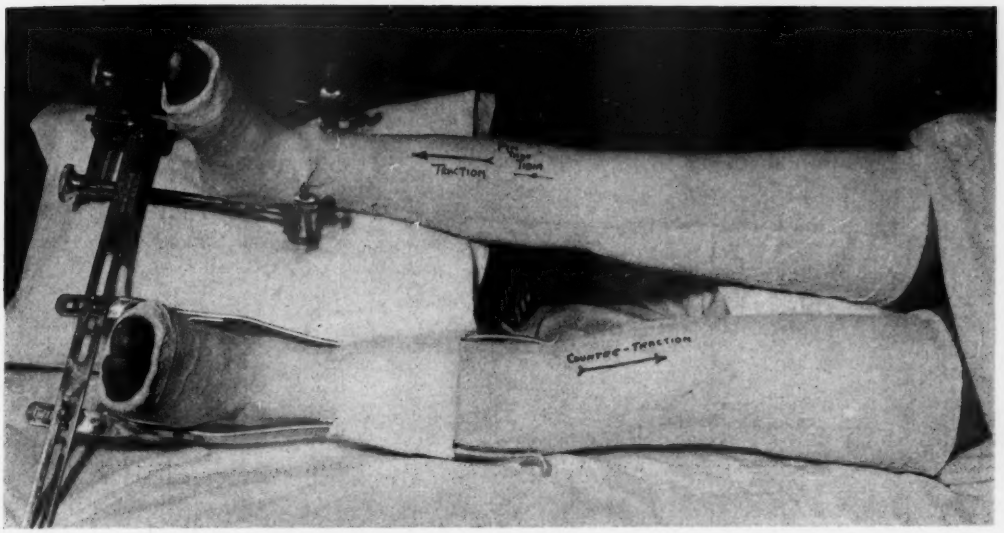


Fig. 15. Well leg traction—Roger Anderson.

Diagnosis. Diagnosis is determined principally by the *x*-ray. The trochanter fragment is displaced upward and backwards due to the pull of the abductors and the short external rotators.

Differential Diagnosis. A major fracture of the greater trochanter is readily recognized. Incomplete or avulsion of the muscle insertion offers the greatest difficulty. The latter is

A B

Fig. 16. A, central dislocation of the femoral head. The entire wall of the pelvis is carried in with the dislocation (ischium valgum). B, reduction of the central dislocation.

easily mistaken for a calcified greater trochanter bursitis.

Treatment. Wide abduction and external rotation may adequately approximate the fragment. Should this manipulation fail, an open reduction must be performed, with fixation in plaster of Paris spica for six weeks.

Prognosis. Excellent.

B. *Lesser Trochanter.* This, as in the case of the greater trochanter, is a very unusual fracture (Fig. 11). The fracture is produced by indirect force and is due to violent contraction of the iliopsoas tendon. It is usually seen in adolescents. (There is probably an underlying osteochondritis similar to Legg-Perthes, Osgood-Schlatter's disease, etc.)

Physical Signs. Active hip flexion is restricted and painful. Pain is intense at the site of the

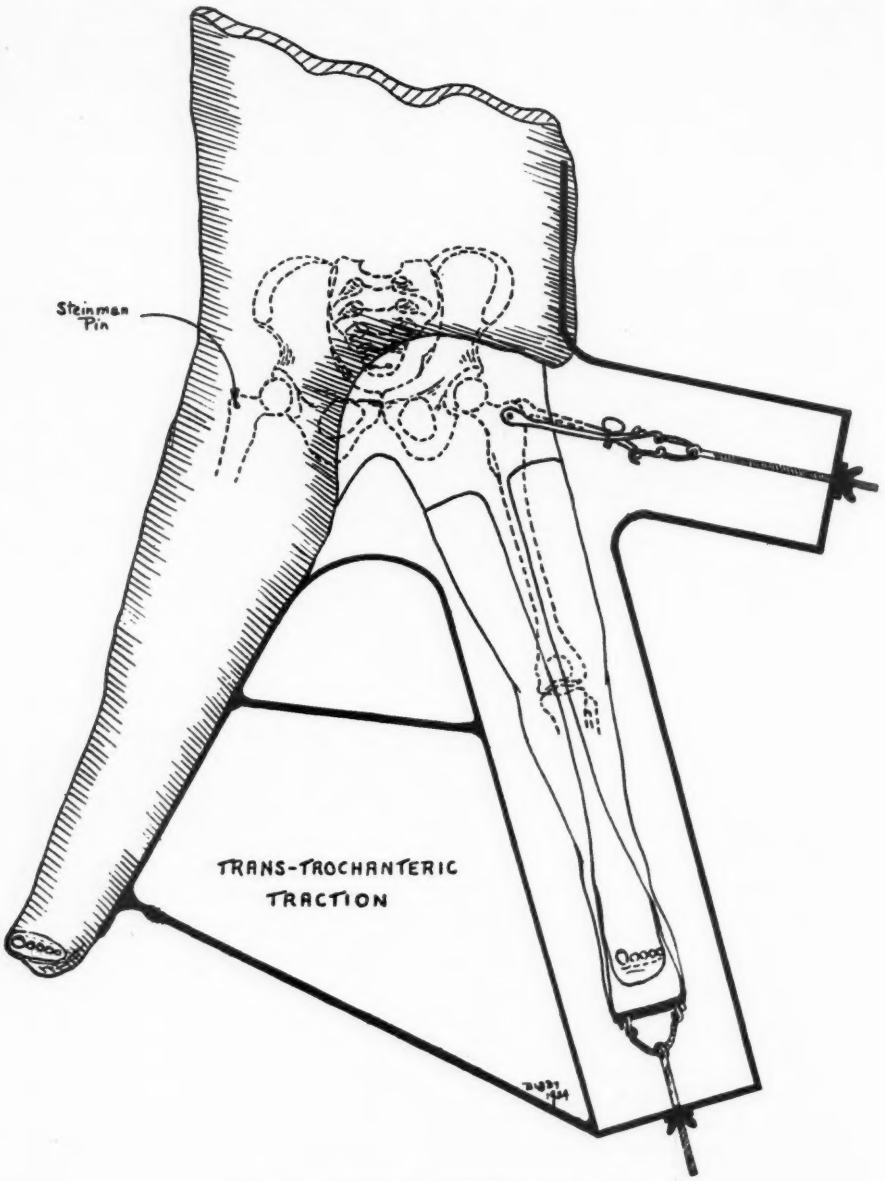


Fig. 17. Transtrochanteric traction.

lesser trochanter on passive hyperextension and internal rotation. The thigh is usually flexed, abducted, and externally rotated. There is deep tenderness over the lesser trochanter area.

Diagnosis. Determined by *x*-ray.

Differential Diagnosis. Complete separation of the lesser trochanter is easily recognized. Incomplete separation must be differentiated from iliopectineal bursitis.

Treatment. The thigh is immobilized in plaster of Paris spica. The thigh is flexed and externally rotated. It is held for six weeks.

Prognosis. Excellent. (Fig. 11B.)

C. *Intertrochanteric, Pertrochanteric, and Subtrochanteric.* (Figs. 12A and B, 13, 14, and 15.) These fractures are also known as fractures of the aged.

Etiology. Direct force. The patient falls in such a manner that the entire force is applied directly to the greater trochanter. Were the trochanteric area to remain intact, a central dislocation would probably occur.

Physical Signs and Symptoms. Similar to those of cervical fractures except that the general shock is more pronounced.

Diagnosis. Established by the *x*-ray.

Treatment. Application of the well leg traction.

Note. The above fractures may be simple or comminuted. Displacement may be mild or pronounced. Union seems inevitable in this group. Malunion, due to inadequate reduction and immobilization is common. Traction and mild internal rotation are essential to reduction. The well leg traction principle as suggested by Hoke, Jones, Steindler, and others, offers the most consistent success. Elimination of a body cast permits the patient to sit up and have early use of the wheel chair. Fixation is indicated for a period of eight weeks. Physiotherapy to restore the ankle, knee, and hip motion is usually necessary for six months.

4. *Fracture Dislocations of the Hip Joint.*

A. *Central Dislocation of the Femoral Head.* Pure central dislocation of the femoral head with fracture limited primarily to the acetabular wall is a comparatively infrequent injury.

Etiology. Indirect force. The fracture is produced usually by great violence—the force being applied squarely against the greater trochanter in the direction of the line of the femoral neck and head. The head is driven through the acetabular wall and usually projects within the pelvis.

Physical Signs. Intense pain at the site of the hip joint. The patient is usually in rather severe shock. There is a slight shortening and a very marked restriction in hip movement with the exception of flexion. On rectal examination, the head of the femur or the bulging acetabular wall can be felt through the rectal wall. The greater trochanter is less prominent, and in some instances is located with great difficulty due to its central displacement.

Diagnosis. *X*-ray shows a characteristic dislocation of the femoral head.

Treatment. Manipulation—consists of forced abduction combined with lateral traction. This usually restores the head to its normal position. The fragments in the acetabulum can

sometimes be moulded back into place through the rectum.

Fixation in a plaster cast is most suitable for the management of this type of fracture. Fixation for twelve weeks is

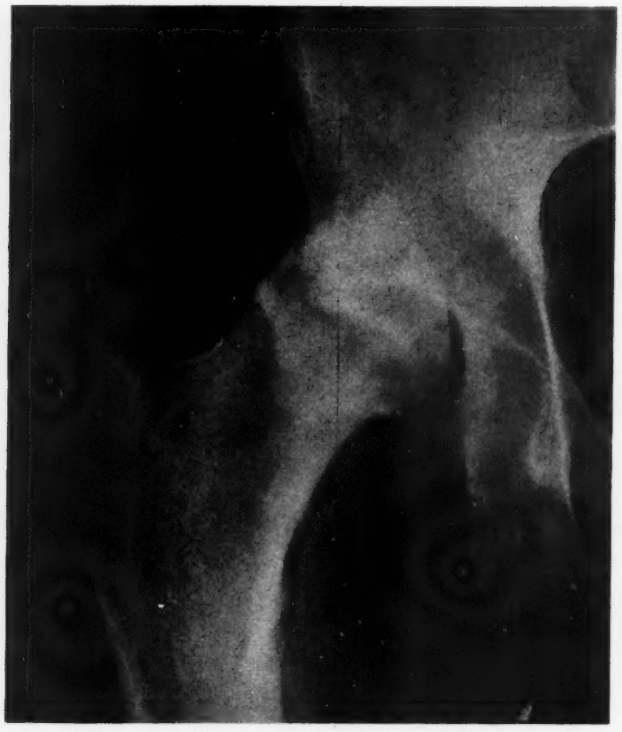


Fig. 18. Posterior dislocation. Note the rim fracture of the acetabulum.

sufficient very often—fixation to be held for ten weeks. Should redislocation occur, then transtrochanteric traction is advisable. (Fig. 17.) Partial weight bearing with crutches is permitted for six months.

A central dislocation of the femoral head may occur and is complicated by a collapse of the entire lateral pelvic wall (ischium valgum). (Fig. 16.)

Physical Signs. Similar to those of pure central dislocation except for the additional tendency to internal injury, injury to the sciatic nerve, and pronounced shock.

Diagnosis. Determined by the physical signs and the *x*-ray.

Treatment. Transtrochanteric traction (Fig. 17) seems necessary and partial weight bearing with crutches for six months is advisable.

Prognosis. Good for a useful hip in the majority of cases providing reduction is adequate.

B. *Posterior Dislocation of the Femoral head Accompanied by Fracture of the Acetabular Rim.*

Etiology. Violent force applied to the thigh in the direction of the femoral head. The thigh is adducted and flexed—similar to the position predisposing to capital, subcapital fractures and posterior-superior dislocation of the hip. The posterior-superior rim of the acetabulum is carried away with the dislocating head.

Clinical Signs. Similar to those of posterior-superior dis-

location of the hip except for the presence of crepitus.

Diagnosis. The diagnosis is established by *x*-ray.

Differential Diagnosis. This injury must be distinguished from pure posterior-superior dislocation of the hip, capital and subcapital fractures.

Treatment. Manipulation—same maneuver as employed in reduction of the posterior superior dislocation; namely, traction on the thigh with the hip flexed adducted. Fixation can usually be obtained by encasing the abducted and externally rotated lower extremity in a plaster of Paris spica of the hip. Should the acetabular rim fail to become replaced an open reduction with pegging of the loose fragment is positively essential.

Prognosis. Depends entirely upon the success and maintenance of reduction.

CONCLUSION

As presented in the introduction, fractures of the upper end of the femur, including fracture dislocations at the hip joint, form one of the most difficult of all fracture problems. The methods referred to in the preceding description are those found, by elimination, to be the most useful to the writer. Most of them are in common usage. In closing, it is extremely important to call attention to the fact that fractures involving the neck, the head and the acetabulum frequently bring about delayed changes in the hip joint after a few years. Arthritis, disintegration of the femoral head and the acetabulum are by no means unheard of sequelae. These complications should always be kept in mind before pronouncing a final judgment in regards to complete repair.

REFERENCES

Albee, F. H. Autogenous bone peg as primary treatment for fresh fractures of the neck of the femur. *Calif. & West. Med.*, 37: 1 (July) 1932.

Albee, F. H. Importance of restoration of blood supply in fractures of the neck of the femur. *J. A. M. A.*, 110: 2044 (June) 1938.

Anderson, R. A new method for treating fractures utilizing the well leg for countertraction. *Surg., Gynec. & Obst.*, 54: 207 (Feb.) 1932.

Burman, M. S. Gridding the femoral head and neck areas in fractures of the neck of the femur for simpler guidance and placement of the Smith-Petersen three-flanged nail. *Am. J. Surg.*, 34: 237, 1936.

Buck, G. An improved method of treating fractures of the thigh. *Tr. New York Acad. Med.*, 2: 233, 1861.

Campbell, W. C. Central or intracapsular fractures of the neck of the femur. *South. Surg.*, 2: 1 (March) 1933.

Campbell, W. C. Ununited fractures of the neck of the femur. *Surgery*, 1: 499 (April) 1937.

Campbell, W. C. Posterior dislocation of the hip with fracture of the acetabulum. *J. Bone & Joint Surg.*, 18: 842 (Oct.) 1936.

Carrell, W. B. A report on the application of the Smith-Petersen nail in fresh fractures of the neck of the femur by adoption of a simplified technic. *South. M. J.*, 28: 583 (July) 1935.

d'Aubigul, R. M. Bony union in fractures of the true neck of the femur. *J. de chir.*, 48: 630, 1936.

d'Harcourt. A contribution to pathology and surgical treatment of recent fractures of the neck of the femur. *Rev. Sanid. de Guerra*, June, 1937.

De Las Casas, H. Fracture of the neck of the femur in the aged. *Bol. Hosp.*, 35: 591, 1937.

George, A. W., and Leonard, R. D. Ununited intracapsular fractures of the femoral neck roentgenologically considered. *Am. J. Roentgenol.*, 31: 433 (April) 1934.

Gaenslen, F. J. Subcutaneous spike fixation of fresh fractures of the neck of the femur. *J. Bone & Joint Surg.*, 17: 739 (July) 1935.

Greer, J. M. Another method of pinning fractures of the neck of the femur. *Southwest. Med.*, 22: 213 (June) 1938.

Hey Groves. The modern treatment and results of treatment of fractures of the neck of the femur. *Brit. M. J.*, 11: 359, 1937.

Heister, L. A General System of Surgery. W. Innys, 1743.

Henderson, M. S. Recent fracture of the hip. Smith-Petersen nail inserted over Kirschner wires. *Proc. Staff. Meet., Mayo Clin.*, 9: 203 (April) 1934.

Henderson, M. S. Internal fixation for recent fractures of the neck of the femur. *Ann. Surg.*, 107: 132 (Jan.) 1938.

Inclan, A. Improved technique of immobilization with the Smith-Petersen nail for osteosynthesis of fractures of the femoral neck. *Cir. Ortop. y. Traumatol.*, 4: 5, 1936.

Johansson, S. An operative treatment of medial fractures of the neck of the femur. *Acta. ortop. Scandinav.*, 3: 362, 1932.

Johnson, C. R. A new method for roentgenographic examination of the upper end of the femur. *J. Bone & Joint Surg.*, 14: 859 (Oct.) 1932.

Jones, C. P. Intracapsular and intertrochanteric fractures of the femur and fractures of the pelvis. *Calif. & West. Med.*, 36: 79 (Feb.) 1932.

Jostes, F. A. Fracture of the acetabulum with central dislocation of the head of the femur. *J. Bone & Joint Surg.*, 18: 483 (April) 1936.

Key, J. A. Insertion of Smith-Petersen nail for intracapsular fractures of the neck of the femur. *Am. J. Surg.*, 36: 466 (May) 1937.

King, M. J. Recent intracapsular fractures of the neck of the femur. *M. J. Australia*, 1: 5 (Jan.) 1934.

Kolodny, A. The architecture and blood supply of the head of the femur and their importance in the pathology of fractures of the neck. *J. Bone & Joint Surg.*, 7: 575 (July) 1925.

Langan, A. J. The use of the Jones splint in the treatment of fractures of the pelvis and of the neck of the femur. *J. Bone & Joint Surg.*, 17: 435 (April) 1935.

Leadbetter, G. W. A treatment for fractures of the neck of the femur. *J. Bone & Joint Surg.*, 15: 931 (Oct.) 1933.

Lippmann, R. K. Corkscrew-bolt for compression-fixation of femoral neck fractures. *Am. J. Surg.*, 37: 79 (July) 1937.

Magnuson, P. B., Fracture of the neck of the femur. Evaluation of the various methods advanced for treatment. *J. A. M. A.*, 107: 1439, 1936.

Mitchell, J. I. Fracture of the neck of the femur in children. *J. A. M. A.*, 107: 1603, 1936.

Paré, A. Works. T. Cotes & R. Young, 1634.

Phemister, D. B. Fracture of the neck of the femur, dislocation of the hip and obscure vascular disturbances producing aseptic necrosis of the head of the femur. *Surg., Gynec. & Obst.*, 59: 415 (Sept.) 1934.

Russell, R. H. Fracture of the neck of the femur. *Brit. J. Surg.*, 11: 491 (Jan.) 1924.

Smith-Petersen, M. N. Treatment of fractures of the neck of the femur by internal fixation. *Surg., Gynec. & Obst.*, 64: 287 (Feb.) 1937.

Siris, I. E., and Delaney, C. J. Fractures of the shaft and neck of the femur. *Am. J. Surg.*, 32: 277, 1936.

Speed, J. S. Central fractures of the neck of the femur. *South. Surg.*, 7: 19 (Feb.) 1938.

Speed, K. The unsolved fracture. *Surg., Gynec., & Obst.*, 60: 341 (Feb.) 1935.

Telson, D. R., and Ransohoff, N. S. Treatment of fractured neck of the femur by axial fixation with steel wires. *J. Bone & Joint Surg.*, 17: 727 (July) 1935.

Watson-Jones, R. Fractures of the neck of the femur. *Brit. J. Surg.*, 23: 787 (April), 1936.

Whitman, R. A new treatment for fractures of the neck of the femur. *M. Rec.*, 65: 441 (March) 1904.

The proteins of milk and eggs contain the most complete supply of amino acids. Meats come next, with kidneys and liver better than the muscle meats.

TREATMENT OF FRACTURES OF THE CARPAL END OF THE RADIUS BY TRACTION

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FRACTURES of the carpal end of the radius in adults may be regarded as unsatisfactory fractures to treat. Rarely is the end result satisfactory to both the patient and the attending surgeon. Slight deformities in this area receive undue notice on account of the ease of comparing it with the opposite or normal wrist and the difficulty of constantly concealing it from the observation of critical companions. Platt[1] quotes Grasby and Trick as follows: "After an examination of fifty cases treated at Guy's Hospital . . . in a Colles fracture with displacement the result after two years is invariably unsatisfactory."

The writer has seen what he regarded as an excellent reduction of a fracture in this area gradually assume the typical deformity of the excessively prominent ulna and the shifting of the hand toward the radial side. This deformity occurred more often in the comminuted type of fracture and in middle aged and elderly women who fractured their wrists in the area associated with the name of Colles. The use of the Roentgen ray places the site of fracture closer to the lower end of the radius than Colles described it in his report in the *Edinburgh Medical Journal* in 1814.[2] For the purpose of this paper I will confine it to the treatment of fractures of the lower end of the radius with or without an associated fracture of the styloid process of the ulna.

FIG. 1. How we would expect to hold the position after the reduction of a fracture of the lower end of the radius. Accomplished by the use of the constant traction shown in Figure 3.

A very thorough search of the literature will show that few changes have taken place in the treatment of this fracture since Colles' time, with the exception of the use of anesthesia and the use of plaster of Paris material in splinting. One observer[3] has found in a mummy exhumed in Egypt the

fracture with splints intact, showing anterior and posterior wooden supports and resembling splints used today in all parts of the world.

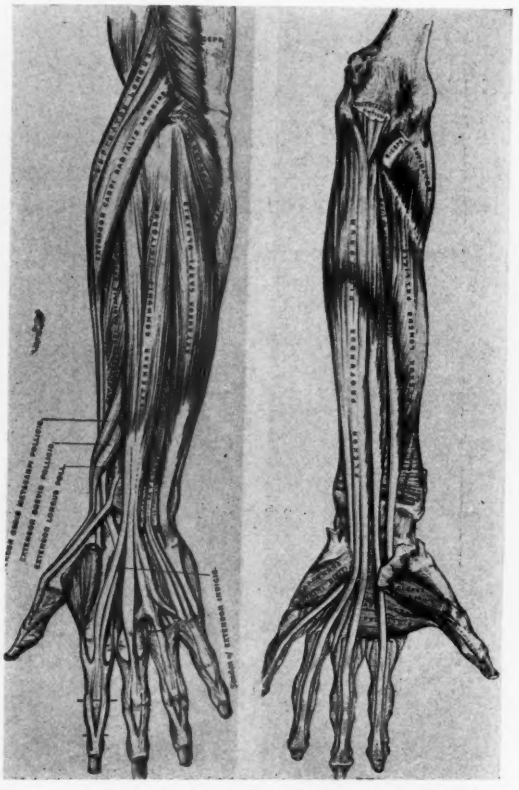

FIG. 2. A diagram from Gray's Anatomy showing the strong tendons crossing the fracture line in the Colles' type of fracture. The constant pull on the lower fragment, if unopposed, causes the shortening and consequent deformity of the radius.

A great improvement has been noted in the treatment of most of the other fractures of bones of the body during the last several decades. It does not seem that the end results in the Colles type of fracture have shared this general improvement. The honor or dishonor of the title of "the unsolved fracture,"[4] was applied some years ago to the fracture of the neck of the femur, but the improved method of treatment by nailing seems to be solving the difficulties associated with this fracture. The treatment of the Colles type of fracture remained in my hands unsatisfactory. As in fractures of the neck of the femur a gradual melting away of the visible bone substance seemed to take place. Research carried out in many quarters on the subject has not helped the surgeon materially nor has it shown the exact cause of this absorption. Strangely, enough, although nonunion is seen frequently in fractures of the neck of the femur it is rarely seen in fractures of the Colles type.

When a fracture of the radius is associated with a fracture of the shaft of the ulna at the same level in the wrist, the deformity does not occur, as both bones shorten equally and slightly in the process of healing. The deformity seems to take place when the radius alone or when the styloid process and not the shaft of the ulna is involved.

In the writer's experience, the usual manner of splinting did not prevent shortening of the radius from developing. After many humiliating experiences, a method of splinting with traction has been devised which may be used practically and without complicated apparatus in almost every fracture in this area in which shortening of the radius alone is apt to occur.

DESCRIPTION OF METHOD

First of all the treatment of this fracture must be taken seriously and deliberately. The kitchen table or the family davenport has no place in the method to be described. If the patient has recently taken food, a reasonable length of time must be allowed for it to pass out of the stomach. In proper surroundings and with adequate assistance, the patient is anesthetized by the method suitable to the individual patient. The fracture is reduced *accurately* and *completely* by one of the many methods. The writer uses a combination of many methods, making sure that any deforming impaction is broken up. The completeness of the reduction is checked by *x*-ray.

The skin at the base of the thumb and the first metacarpal is then painted with compound tincture of benzoin. A loop of double thickness adhesive, or moleskin 1½ to 2 inches wide is wrapped about the base of the thumb, the first metacarpal and the index finger, as shown in Figure 6. The

ends of the adhesive loop, overlap or cross in such a manner that it is capable of sustaining a reasonable pull. A second strip applied transversely prevents slipping. Stockinette is placed as high up as the mid-humerus and a strip of felt ½ inch in thickness is attached to the front of the upper arm, passing downward past the crease of the elbow. A light and practically unpadded plaster of Paris cast is applied from the palm of the hand to the mid-humeral region. Incorporated in the cast is a traction apparatus or a banjo type of splint made of strong wire or a light metal, such as duralumin. A rubber strip or a spring (Fig. 4) connects the adhesive loop to the metal part of the splint[4] and maintains reduction until such time as the compressed area on the back of the radius has become filled in with new bone or organized tissue of sufficient stability to withstand and counteract the pull of the strong muscles and tendons crossing the fracture line. (Fig. 2.) The tension maintained in this manner carries the carpus to the ulnar side and prevents dislocation taking place at the inferior radio-ulnar joint. The hand is placed in slight supination, or midway between pronation and supination. In compound fractures, double pins may be used (King[5]). If the skin is intact the writer finds that pins or wires are unnecessary.

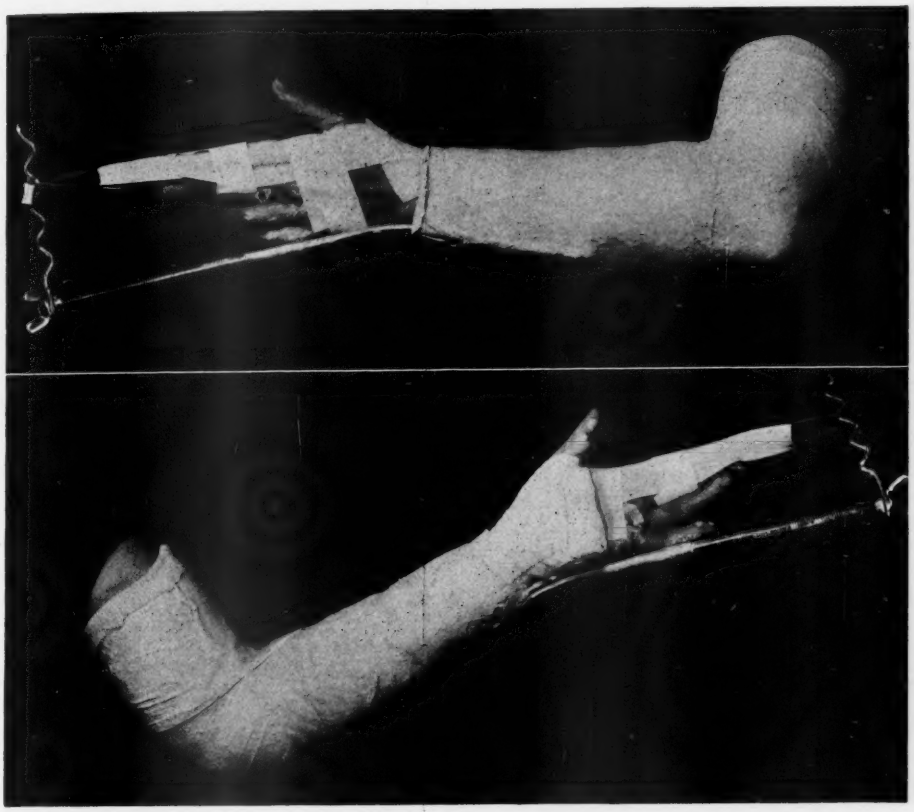

Fig. 3. Constant tension on the thumb and index fingers to counteract the deforming influences of the intact tendons.

It is fundamental that the fracture be thoroughly reduced before applying this method of splinting. This is not to be regarded as a method of reduction, but as a method of maintaining reduction. Successful immobilization of "the joint above and the joint below the fracture line" is achieved. Frequent examination with fluoroscope or film is possible. The lower fragment remains under our control and minor adjustments may be carried out easily.

In the average patient a smaller cast may be applied and the traction apparatus

removed after the twenty-first day, but if there has been much comminution it should be left intact for four or five weeks. A pistol grip or a sugar tong-shaped splint may be used for comfort for three more weeks.

Fig. 4. Traction or tension applied with a portion of the cast cut out to show the position of the adhesive strips. Tension maintained with a spring register.

The errors I have observed in this method of treatment have been due to too much tension, which is apt to pull the strips loose; or in too little tension which may be valueless. The use of a lower arm cast alone is incorrect also. I have found that the equivalent of the use of 3 or 4 pounds of weight will overcome the deforming influences.

Fig. 5. The wrong way to apply this method. The plaster of Paris should include the elbow joint to prevent supination and pronation.

Fig. 6. Showing loop of adhesive applied to the thumb and index fingers.

It is difficult to compare various methods with regard to the amount of stiffness of the fingers and wrist which follows, since stiffness varies in degree according to the individual. There seems to be some relationship between the accuracy of the reduction and the restoration of normal mechanics at the wrist joint and the amount of stiffness and arthritic manifestations which develops. Much of the stiffness is due to injury to the tendons and tendon sheaths and hemorrhage or effusion into them. The method of treatment here proposed, by maintaining the tissues at their maximum length in the position of function, seems to lessen the amount of residual stiffness.

After using or supervising the use of this method in over eighty instances, I have seen shortening of the radius approaching a degree which could be described as unsatisfactory in only five.

SUMMARY

1. Deformity may be prevented from developing in a perfectly reduced fracture of the Colles type or in the comminuted fracture of the carpal end of the radius by continuous traction or tension for at least three weeks.

2. Adhesive strips applied to the radial half of the hand and attached to a splint buried in a cast which extends to the upper arm will accomplish this.

REFERENCES

1. Platt. *Brit. M. J.*, August, 1932.
2. Surgeon General's Library.
3. Magnuson. *Surg., Gynec. and Obst.*, 62: 276, 1936.
4. Speed. *Surg., Gynec. and Obst.*, 60: 341, 1935.
5. King. *M. J. Australia*, July 30, 1932.

DASHBOARD FRACTURES OF THE PATELLA*

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DURING the past thirty years we have witnessed the progress of the automobile through its progressive stages of development until it now plays a major rôle in the daily life of every one of us. Keeping pace with this mechanical advance we have also seen a steady increase in the frequency and severity of highway accidents. The orthopedic and traumatic surgeon has been confronted with a variety of bizarre and unusual injuries, certain of which are becoming recognized as typical automobile injuries because of the frequency of their occurrence in this connection.

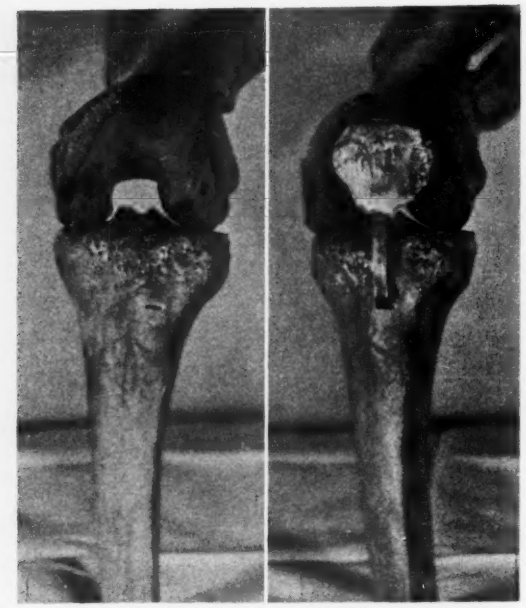
A severely comminuted fracture of a portion of the patella is often the result of automobile accidents in which, due to the shock of collision or quick stopping, the victim is thrown forward and the tensed knee-cap strikes forcibly against the dashboard or other projection of the interior of the car. In a review of forty-three consecutive cases of fractured patella treated in the hospitals of Lincoln, Nebraska, twenty-nine, or 67½ per cent, were the result of automobile accidents. Three of these were automobile-pedestrian accidents while twenty-six, or 60 per cent, were definitely dashboard fractures. The severity of these dashboard fractures is indicated by the fact that nineteen of these twenty-six cases required open operative treatment. A careful study of statistical reports on fractures of the knee-cap, published from fifteen to twenty-five years ago,[7] would indicate that these severely comminuted fractures are occurring much more frequently at the present time, and it is evident that automobile injuries are largely responsible for this increase.

Due to the low osteogenic properties of the patella and the prolonged disability resulting from so-called conservative treatment, open operation and fixation has become the method of choice in the treatment of fractures presenting any considerable displacement.[1,5,6,8] This procedure has, in the hands of competent men, resulted in a high percentage of satisfactory results, and seems to be especially effective in transverse fractures where accurate reduction and fixation can be obtained. However, in cases presenting any considerable comminution the problem of reduction and fixation is extremely difficult, and in many instances accurate reduction cannot be maintained. In these cases bony union is delayed; disability is prolonged; atrophic changes occur; and the hope of obtaining a good functional result is definitely less than in the simple transverse fractures. Even when bony union has occurred in such a case, the roughening and irregularity of the articular surface of the bone predisposes to the occurrence of arthritic changes in the knee joint.

These difficulties occurring in severe fractures of the knee-cap have been recognized since the open operative method of treatment became practicable. Heineck,[7] in 1909, in reviewing 1,100 cases of fractured patella collected from the literature, found five cases reported in which complete excision of the patella had been done because of severe fracture, and in which satisfactory functional results were obtained. A number of cases were also reported in which a loose fragment had been removed. Thomson,[9] in 1934, called attention to the good result following complete excision of comminuted fragments in cer-

* From the Orthopedic Clinic of J. E. M. Thomson and C. F. Ferciot, Lincoln, Nebraska.

tain instances where either the upper or lower pole of the patella was comminuted, following which the tendinous apparatus



A B

Fig. 1. A, note the extensive articular cartilage exposed when the knee is flexed. B, the patella acts as a bony pad protecting the articular surface.

was sutured directly to the remaining fragment. Henderson, in discussing patellar fractures in 1935,[4] stated that "When the lower fragment is very small it can be

Table I

Mode of Injury	Injured		Requiring Open Operation	
	No.	Per Cent	No.	Per Cent
Auto accidents	29	67.5	20	70
Dashboard fractures	26	60	19	73
Falls	14	32.5	8	57

removed entirely and not be missed." Blodgett and Fairchild,[2] in 1936, reported eight cases of total excision of the patella for acute fracture with satisfactory results. The younger patients were able to return to heavy work after three months. They also treated nine cases by excision of fragments at the upper pole, and three cases by excision of fragments at the lower pole. No tendency of the patella to regenerate was found in any case. Brooke,[3] in 1937, reported thirty cases in which the patella had been completely excised for acute fracture. Full functional recovery was reported in all cases with a decided shortening in the period of expected disability.

There are relatively few references in the literature discussing the function of the knee-cap to any length, the general consensus of opinion seeming to be that it is just another one of those sesamoid bones. Some have felt that it improved the mechanical advantage of the quadriceps force in certain positions, and further, that it added to the stability of the knee joint in the extended position. More recently, however, its function has been the subject of careful investigation, and Brooke[3] reports that its complete removal does not weaken the knee joint, but rather adds somewhat to the smoothness and celerity of motion response. His experimental work appears conclusive that it adds little to the mechanical advantage of the knee joint, and clinical reports of function following removal would seem to bear out his impression that the patella is a morphologic remnant which serves no important function.

Table II

TABLE OF END RESULTS OF CASES FOLLOWED

Method of Treatment	Total Number Treated	Good Results	Fair Results	Comminuted	Average Weeks Disability
Open fixation of fragments	6	4	2	2	17.65
External fixation only	6	6	0	0	10.65
Excision of fragments and suture	8	8	0	8	10.75
Totals	20	18	2	10	12.9

After reviewing this series of cases, however, in which severe injury to the knee-cap was so common, the writer is impressed with the thought that the function of the patella in protecting the extensive articular cartilage of the lower end of the femur from

direct trauma deserves, perhaps, more consideration than it has been accorded. Projecting forward as it does in the intercondylar space, the patella forms an excellent buffer mechanism for the knee joint, particularly in the flexed position. Without its protection, a large portion of the articular surface of the femur would be exposed to the insult of repeated injury. The fact that this bone exhibits extremely low reparative powers lends further credence to the impression that its function is largely protective in nature, and that it has been adapted to perform this function. If

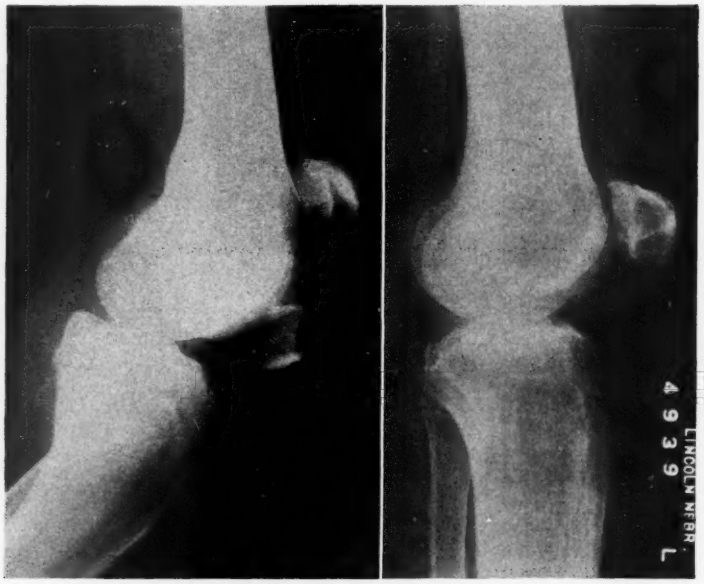
A B

FIG. 2. A, dashboard fractures with some comminution. B, note position of remaining fragment two years later. It affords adequate protection to the knee joint.

A B

FIG. 3. A, compound comminuted fracture resulting from a fall. B, appearance one and one-half years after excision and repair.

it possessed high osteogenic powers the repeated trauma to which it is continually subjected would result in extensive pro-



A B

FIG. 4. A, severely comminuted dashboard fracture in patient aged 68. B, one year after excision of fragments and suture of tendon.

liferative changes, which would soon have a deleterious affect upon the knee joint itself.

Reports of the period of disability following fracture of the knee-cap vary considerably, some authors reporting as low as from three to four weeks, and others as high as from three to six months. Some variation in criteria for determining the end of disability doubtless accounts for a considerable part of this seeming discrepancy. A bookkeeper may be able to get about fairly well and do his usual work in a considerably shorter time than a ditch digger, and it would seem that if actual disability was considered to exist until the individual was able to do heavy duties that the statistical results might be more uniform, or at least would have more meaning. In the present series twenty cases could be traced definitely, and the period of disability was estimated to that time when the patient was able to resume heavy duties with a range of at least 90 degrees motion and good quadriceps strength.

Six cases were treated by external fixation only, with a period of disability averaging 10.65 weeks. Six cases were treated by open operation and fixation with an average period of disability of 17.65 weeks. In eight cases of comminuted fractures treated by excision and primary suture of the remaining fragment to the extensor apparatus, the average disability was 10.75 weeks; only slightly longer than those cases of fracture presenting little or no separation, which were treated by external fixation only. Of the six cases treated by casts alone, all had good functional results. Of the six cases treated by open reduction and fixation, four had good results and two only fair. Of the eight comminuted cases treated by excision and primary suture all had good end results. In no instance was it felt necessary to excise the entire patella, although in certain severely comminuted cases this procedure might be warranted.

In one case treated by excision of fragments and direct tendon suture, disability was prolonged to sixteen weeks. This case deserves special mention because it emphasizes the importance of proper after-care.

In this instance coöperation could not be obtained and the knee was kept immobilized for one month when the patient failed to return as requested. At this time the patellar fragment was found in good position. This patient was not seen again for two months, during which time he carried out daily stretching of the knee to increase motion, and got about only with the aid of crutches. At the end of this period the newly repaired tendon was found to be lengthened over an inch, the patellar fragment riding high, and the quadriceps muscle very weak. Tendon shortening was refused but an active exercise program was agreed upon. At the end of a month the patient was able to demonstrate full range of motion with good quadriceps strength, although the patellar tendon was no shorter.

While this series is admittedly too small to allow any final conclusions, it is the impression of the author that the period of disability to be anticipated following any severely comminuted fracture of the patella, in which one fair-sized fragment remains either at the upper or lower pole, is greatly reduced by early excision of the comminuted fragments and direct suture of the extensor apparatus to the remaining fragment, together with careful repair of all injuries to the lateral extensor apparatus. The saving of a portion of the patella retains effectively the protective function which we feel it subserves in relation to the knee joint.

The operative procedure used in these cases is essentially that reported by Thomson[9] in 1934. A free lateral patellar incision exposes the fracture site fully when the skin and subcutaneous tissue have been reflected. The fragmented portion of the bone is carefully excised and the blood clots removed from the anterior chamber of the knee. Two drill holes are placed longitudinally through the remaining fragment in such a way as to afford firm anchorage to a strong kangaroo tendon or living fascia suture. This suture is then imbricated in the central portion of the tendinous extensor apparatus, whether it be at the upper or lower pole, and with the knee extended and the patellar fragment approximated,

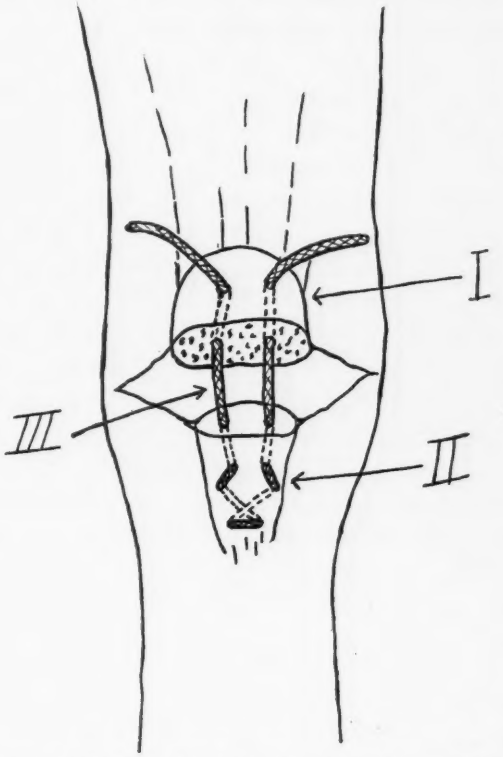


Fig. 5. Method of imbricating suture in patellar tendon. A firm suture, deep in the patellar tendon is essential. Kangaroo tendon preferred because of strength, availability, and ease of use.

the suture is passed through the drill holes and firmly tied. Careful repair of any lateral tears of the capsule is made, and the superficial portion of the ligament approximated, after which 20 c.c. of amniotic fluid are injected into the joint space and the wound closed. The use of amniotic fluid in the knee joint following arthrotomy has been practiced routinely for the past four years, and clinically we have felt that postoperative reaction is lessened and functional recovery accelerated, probably by minimizing the formation of interarticular adhesions and reduction of hemorrhage.

A posterior straight leg splint is applied and the patient is allowed to be about with crutches at the end of six to ten days. Early active motion is instituted in from ten to fourteen days, and splinting is discarded

in from fourteen to twenty-one days, the patient being instructed to bear weight in the straight leg position and increase the range of motion as rapidly as possible by active use. Muscle training and massage are very helpful in aiding early activity and definitely shorten the period of disability. Passive stretching is never used. After three to four weeks the patient is encouraged to discard crutches and get about with a cane only. At first motion is usually quite limited, but with early active function contracture of the powerful quadriceps muscle is prevented and, as the sutured patellar tendon becomes stronger, the range of motion is gradually increased by the activity of the patient and the quadriceps muscle lengthens the small amount necessary to accommodate the new relationship. Several have returned to clerical and light occupations at the end of two to four weeks. We have not observed any case in which a full functional recovery occurred in less than eight to ten weeks. It has been our practice to delay operation on these cases for a period of twenty-four to seventy two hours, during which time the leg is immobilized in a posterior splint; shock is overcome; the swelling reduced by a compression bandage, ice bags or aspiration; and the skin properly prepared for surgery. Complicating injuries are not infrequent and must receive adequate consideration.

CONCLUSIONS

1. Dashboard fractures of the patella are increasing frequently and present an unusual degree of comminution of the bone. Accurate reduction and fixation of these fractures is often impossible.

2. The presence of the patella, although adding little to the mechanical efficiency of the knee, exerts a beneficial influence through its action in protecting the extensive cartilaginous surface of the femoral condyles, and its preservation is urged where possible.

3. Excision of fragmented portions of the bone, followed by suture of the extensor ligaments to the remaining fragment, retains this protective function and shortens the period of disability which follows these severe injuries.

4. Many injuries resulting from being thrown against the interior of a car at the time of accident might be prevented by better designing of automobile interiors. Suitable padding and the use of some type of automobile safety belt is offered as a possible solution.

REFERENCES

1. Allen, A. W. *J. Bone & Joint Surg.*, 16: 640–648, 1934.
2. Blodgett, W. E. and Fairchild, R. D. *J. A. M. A.*, 106: 2121–2125, 1936.
3. Brooke. *Brit. J. Surg.*, 24: 733–747, 1937.
4. Campbell, W. C. *South. M. J.*, 28: 401–408, 1935.
5. Crowley, G. W. *Surg., Gynec. & Obst.*, 64: 1074–1078, 1937.
6. Gallie, W. E., and LeMesurier, A. B. *J. Bone & Joint Surg.*, 25: 47–54, 1937.
7. Heineck, A. P. *Surg., Gynec. & Obst.*, 9: 177–248, 1909.
8. Henry, M. O. *Am. J. Surg.*, 38: 682–690, 1937.
9. Thomson, J. E. M. *J. Bone & Joint Surg.*, 17: 431–434, 1934.

THE ROLE OF THE CORACOCLAVICULAR LIGAMENTS IN AFFECTIONS OF THE SHOULDER GIRDLE*

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THIS study was stimulated by the remark of a mature orthopedist, John Ridlon, who at the meeting of the Chicago Surgical Society in 1922, said " . . . that the difficulties encountered in treatment of injuries to the shoulder joint have always been more troublesome and more obscure than the difficulties in treating all other joints together." We may safely add that these difficulties are, at least in part, due to our limited knowledge of the underlying pathology.

At the United States Public Health Service Out-Patient Clinic in New York City, we had in a period of ten years 4,000 patients who complained of pain in the shoulder girdle, constituting 4 per cent of all persons *x*-rayed at this clinic. Over 98 per cent were male. Merchant seamen and W.P.A. workers of equal number constituted 70 per cent of the total, referred for treatment and for decision on period of disability; longshoremen represented 16 per cent, referred by the Referee Commissioner, for guidance in adjustment of patients' claims against the insurance carriers; United States Employees Compensation Commission cases—9 per cent—referred to the clinic for treatment, or for deciding disability and adjustment of claims; and other beneficiaries—5 per cent —for treatment and claims. Almost all the patients had filed claims, and we had to referee these claims, sometimes before and sometimes after corrective measures had been instituted.

Out of the total number, 1,800 cases were studied in detail; only 28 per cent showed positive *x*-ray findings on the ordinary anteroposterior view. With the addition of the oblique view which we instituted in 1928 in accordance with the suggestion of King and Holmes[1] of Massachusetts General Hospital, the number of positive cases was increased to 32.4 per cent. The reasons for this low percentage of positive *x*-ray findings have been discussed in one of our recent publications.

This communication deals with the thirty-six patients who had abnormal *x*-ray findings pertaining to the coracoclavicular region. Since this topic has received so little mention and attention, it is desirable to review it.

Picture a woman of 38, lifting a wash boiler from the stove to the floor. She is startled by something dropping on the floor with a bang, and conscious that she is losing her grip on the handle in her right hand and aware of the boiling water in the boiler, she strains herself with all her energies to hold up the other end to minimize the injury. Nevertheless she sustains a scald on her left foot, an incomplete fracture of the great toe of the left foot, and pain in the left shoulder. A week later the burn and fracture of the foot trouble her no longer, but she persists in complaining of pain in her left shoulder. We say she sprained the shoulder. What does that mean? What has happened to it? In what way can we remedy her disability and discomfort?

Or let us take this example: An executive is holding an important telephone conversation. The noise outside his room interfering, he reaches out with his right hand as far as possible to grasp the knob to shut the door. Unable to reach the knob, he grasps the side of the door and in trying to shut it,

* Approved for publication by the Surgeon General, U. S. Public Health Service.

his arm swings backwards. He experiences a slight pain close to the angle of the right scapula, and a much sharper pain in the middle of the upper border of the scapula. For weeks he complains of inability to put on his coat or play golf. He has no tender areas over the subacromial region, but he does have a point of tenderness over the coracoid and another one in the posterior part of the scapula, at a point 1 inch from the middle of the superior border. An *x*-ray examination of the shoulder discloses no abnormality of the scapulohumeral, acromioclavicular, or acromiohumeral region, and hardly any findings in the coracoclavicular region. We diagnose his case "sprain of the shoulder." Wherein lies his trouble?

Or imagine a young football star diving for the ball and landing on his right side. His opponents pile up on his left side, especially the left arm. The humerus does not give, but the whole shoulder does. The scapula is suddenly pushed towards the young man's spine. The clavicle overrides the acromion, and the coracoclavicular ligaments stretch. What is more important, the man can no longer push or pull with the left arm without discomfort and pain even on simple swinging of the arm. He has no evidence of fracture or dislocation of the acromioclavicular joint, but he is incapacitated for the entire season. The condition is also diagnosed "sprain." But of what part?

Or take the case of a longshoreman who had sustained a dislocation of the acromioclavicular joint. For a while his arm was placed in a sling. When this failed to relieve the pain open reduction was done and two loops of wire were placed between the clavicle and the acromion. After a short time he returned to his work and the very same day he again felt a sharp pain in the shoulder. An *x*-ray examination showed that both loops of wire had been broken, incapacitating the patient once more. What made this surgical procedure a failure can best be understood if we review the fundamentals of the entire problem, namely, the basis of support of the upper extremity to the body, the main anchoring of the scapula on the clavicle, and in turn on the body, the limits of this anchoring structure, the coracoclavicular ligaments, the function of these ligaments, the evolution of the ligaments, the part they play in the movements of the upper extremity, and particularly the rôle they play in acromioclavicular dislocations.

I

The upper extremity is joined to the body indirectly, through the intermediary lever—the clavicle—which articulates with the sternum by a very strong capsular and accessory ligament, allowing vertical movement, anteroposterior movement, and axial rotary movement of minor extent.[2] Since the inner arm of this lever—the clavicle—is short, the outer arm (the longer one) has in turn much greater range of movement. To the clavicle at about the junction of the inner three-fourths and outer one-fourth, the scapula is joined by two strong bands placed in such a manner that when one is stretched the other is relaxed. (Fig. 1.) They are somewhat similar to the crucial ligaments of the knee but broader, especially at the clavicular attachment. To understand these important structures—the coracoclavicular ligaments—we had best digress to the evolution of the shoulder girdle in general.

In the lower vertebrates, such as the fish, where the body is supported entirely by the buoyancy of water, the clavicle is flat and is attached to the cleithrum in front, in a way similar to the attachment of the clavicle to the sternum in humans. The coracoid and scapula are represented as a single bone, attached to the clavicle by ONE BAND stretching from the top of the clavicle to the lower part of the coracoid in front and a similar BAND BEHIND. The humeri are short and attached by a universal joint to the scapulocoracoid. This is well adapted for steering and paddling movement; but the fins are not used either for support of the front of the body or for support of the entire body, as in primates. (Fig. 2.)

In the amphibia where the pectoral girdle is used for support and locomotion, a change occurs. The coracoid swings around

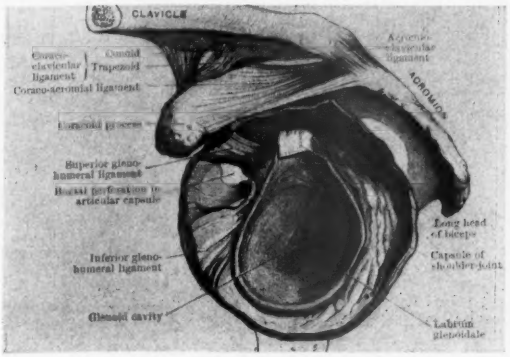

Fig. 1. Relation of the conoid and trapezoid ligaments to each other and to the conoid and clavicle. (After Cunningham.)

and bridges the side of the animal to the front, reaching almost the median line, and the clavicle is just slightly anterior or cephalad to the coracoid. The clavicle is bridged both medially and laterally to the coracoid by means of the remains of a reptilian structure, the precoracoid. The scapula, as continuation of the coracoid, becomes slightly angulated at about the glenoid cavity, facilitating support, steering and paddling functions of the upper extremities. The slight angulation of the scapula and the coracoid on the clavicle has turned the *front connecting band* slightly laterally, and the *back connecting band* of the clavicle slightly medially on the coracoid.

In a further stage of evolution, as in the marsupials, the coracoid is only a remnant seen in the embryo; in the adult animal it has receded laterally and is only a process of the scapula. The scapula has angulated further to the back and with it the front band of the clavicle to the coracoid extended more outward, and the back band more inward. In primates, especially in the human, the scapula is further angulated on the clavicle in order to give freer movement to the upper extremity, greater prehension and suspension functions. This has carried the anterior band of the clavicle more externally and the posterior band of the clavicle more internally on the coracoid; and as a result we have a twist of the coracoclavicular ligament from the anterior part of the clavicle to the postero-external

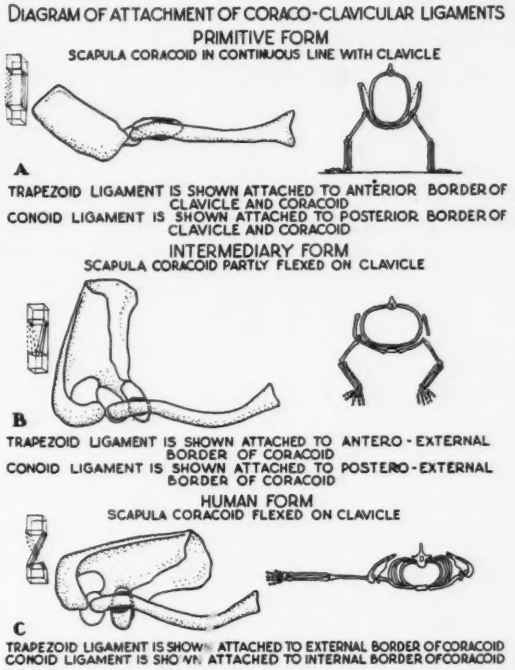
DIAGRAM OF ATTACHMENT OF CORACO-CLAVICULAR LIGAMENTS
PRIMITIVE FORM
SCAPULA CORACOID IN CONTINUOUS LINE WITH CLAVICLE
A
TRAPEZOID LIGAMENT IS SHOWN ATTACHED TO ANTERIOR BORDER OF CLAVICLE AND CORACOID
CONOID LIGAMENT IS SHOWN ATTACHED TO POSTERIOR BORDER OF CLAVICLE AND CORACOID
INTERMEDIARY FORM
SCAPULA CORACOID PARTLY FLEXED ON CLAVICLE
B
TRAPEZOID LIGAMENT IS SHOWN ATTACHED TO ANTERO-EXTERNAL BORDER OF CORACOID
CONOID LIGAMENT IS SHOWN ATTACHED TO POSTERO-EXTERNAL BORDER OF CORACOID
HUMAN FORM
SCAPULA CORACOID FLEXED ON CLAVICLE
C
TRAPEZOID LIGAMENT IS SHOWN ATTACHED TO EXTERNAL BORDER OF CORACOID
CONOID LIGAMENT IS SHOWN ATTACHED TO INTERNAL BORDER OF CORACOID

Fig. 2. Developmental stages of the angulation of the scapulocoracoid to the clavicle and the associated torsion of the coracoclavicular ligaments. The anterior band of the clavicle turns outward with the anterior surface of the coracoid. The posterior band of the clavicle turns inward with the coracoid, resulting in anterior external and posterior internal ligaments respectively, similar to the crucial ligaments of the knee.

part of the coracoid, and from the posterior part of the clavicle to the antero-internal border of the coracoid, similar to the crucial ligaments of the knee. In the adult the ligaments have receded from their borders and have fanned out more on the clavicle than the coracoid. The intervening structure between the two bands has become liquefied into a bursa which keeps the clavicle from grating against the coracoid. Occasionally fibrocartilage intervenes. Huntington[3] claims that the coracoclavicular ligaments and the subscapularis muscle have their origin in the scapulo sternal sheath of embryonal tissue which in lower animals gives rise to the scapulosternal muscles.

Cunningham's[4] description of the ligaments is as follows: "There is the strong

coracoclavicular ligament which binds the acromial end of the clavicle to the coracoid process of the scapula. It is readily divisible into two parts, viz.: lig. conoideum and the lig. trapezoideum.

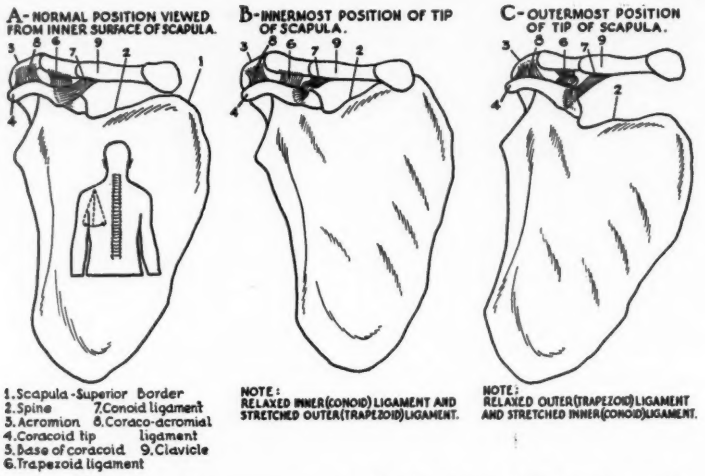
A-NORMAL POSITION VIEWED FROM INNER SURFACE OF SCAPULA.
B-INNERMOST POSITION OF TIP OF SCAPULA.
C-OUTERMOST POSITION OF TIP OF SCAPULA.
1. Scapula-Superior Border
2. Spine
3. Acromion
4. Coracoid tip
5. Base of coracoid
6. Trapezoid ligament
7. Conoid ligament
8. Coraco-acromial ligament
9. Clavicle
NOTE: RELAXED INNER (CONOID) LIGAMENT AND STRETCHED OUTER (TRAPEZOID) LIGAMENT.
NOTE: RELAXED OUTER (TRAPEZOID) LIGAMENT AND STRETCHED INNER (CONOID) LIGAMENT.

Fig. 3. "Pendulous" movement on a horizontal axis. Tip of scapula approaches or recedes from the spine; from back to side of chest.

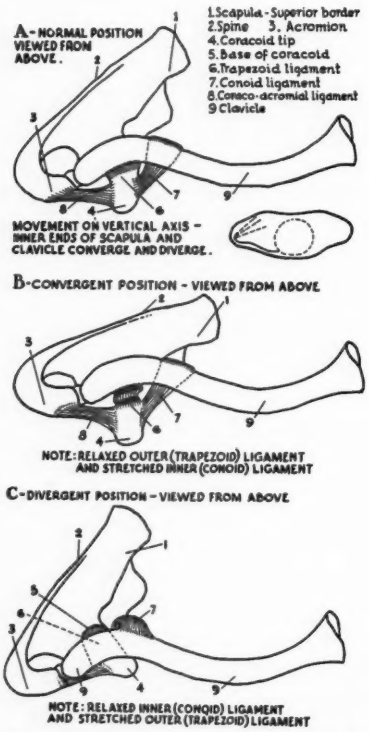
A-NORMAL POSITION VIEWED FROM ABOVE.
1. Scapula-Superior border
2. Spine
3. Acromion
4. Coracoid tip
5. Base of coracoid
6. Trapezoid ligament
7. Conoid ligament
8. Coraco-acromial ligament
9. Clavicle
MOVEMENT ON VERTICAL AXIS - INNER ENDS OF SCAPULA AND CLAVICLE CONVERGE AND DIVERGE.
B-CONVERGENT POSITION - VIEWED FROM ABOVE
NOTE: RELAXED OUTER (TRAPEZOID) LIGAMENT AND STRETCHED INNER (CONOID) LIGAMENT
C-DIVERGENT POSITION - VIEWED FROM ABOVE
NOTE: RELAXED INNER (CONOID) LIGAMENT AND STRETCHED OUTER (TRAPEZOID) LIGAMENT

Fig. 4. "Hinged" movement of scapula on clavicle on a vertical axis; the vertebral border of the scapula approaches or recedes from the clavicle.

"The conoid ligament (Fig. 1) is situated medial to and slightly posterior to the trapezoid. It is narrow and pointed at its inferior end, to which it is attached to the superior aspect of the coracoid process, in close proximity to the scapular notch. Its superior end widens out in the manner expressed by its name, and is attached to the coracoid tuberosity of the clavicle.

"The trapezoid ligament (Fig. 1) is attached inferiorly to the superior surface of the posterior half of the coracoid process, lateral and anterior to the attachment of the conoid ligament. Superiorly it is attached to the ridge on the inferior surface of the acromial end of the clavicle. Its lateral and medial borders are free. Its anterior surface is principally directed upwards and its posterior surface to a similar extent looks downward.

"A mucous or synovial bursa usually occupies the re-entrant angle between these two ligaments."

Once we realize the position of these two ligamentous bands we can then follow carefully the nature of the movement of the scapula on the clavicle which these bands allow. Once more let us state that the major anchorage of the scapula to the clavicle is through the coracoclavicular ligaments; the acromioclavicular ligaments are only a later developed structure, i.e., an accessory stabilizer rather than a primary stabilizer of the shoulder girdle. (Experimental proof is forthcoming.)

II

The movements of the scapula on the clavicle can be best understood if we picture a hinged type of universal joint, hooked to the clavicle on one end and to the coracoid on the other end; with this addition—that the part attached to the coracoid is also pivoted. As a result we have three kinds of movements which are usually associated with each other in life but which can best be analyzed separately. To follow the simile of the universal joint with the pivot, we have one movement in the horizontal plane, the axis of the movement parallel to the spine of the scapula, the top of the scapula moving backward when the lower part of the scapula moves forward, and vice versa. (Fig. 3.) When the top of the scapula is closer to the clavicle the outer band is stretched. When the top of the scapula is further from the clavicle, the inner band is stretched.

The second movement of the scapula on the clavicle is on a vertical axis, at right angles to the former movement, centered on the coracoclavicular ligaments. (Fig. 4.) When the vertebral border comes closer to the back of the patient, the inner band is stretched; when the vertebral border is away from the chest (as in wing scapula) the outer band is stretched.

The third movement on the pivot is on a horizontal axis and could be best described as a pendulous movement of the scapula on the clavicle. (Fig. 5.) The inferior border of the scapula moves closer to the spine, stretching the outer band,

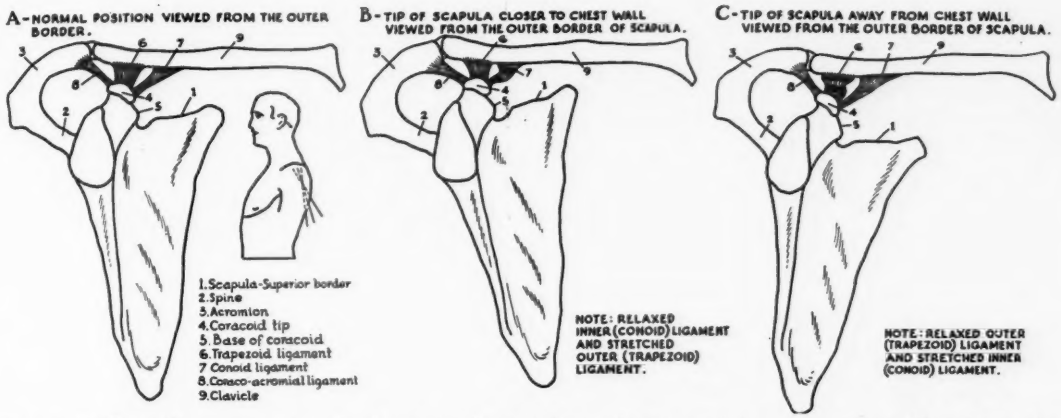
A-NORMAL POSITION VIEWED FROM THE OUTER BORDER.
B-TIP OF SCAPULA CLOSER TO CHEST WALL VIEWED FROM THE OUTER BORDER OF SCAPULA.
C-TIP OF SCAPULA AWAY FROM CHEST WALL VIEWED FROM THE OUTER BORDER OF SCAPULA.
1.Scapula-Superior border
2.Spine
3.Acromion
4.Coracoid tip
5.Base of coracoid
6.Trapezoid ligament
7.Conoid ligament
8.Coraco-acromial ligament
9.Clavicle
NOTE: RELAXED INNER (CONOID) LIGAMENT AND STRETCHED OUTER (TRAPEZOID) LIGAMENT.
NOTE: RELAXED OUTER (TRAPEZOID) LIGAMENT AND STRETCHED INNER (CONOID) LIGAMENT.

Fig. 5. "Winged" movement on horizontal axis at right angles to pendulous movement. Tip of scapula approaches or recedes from the chest wall.

and when it moves away from the spine it stretches the inner band. In addition there is a combined movement in pulling and pushing that one must understand clearly. In pushing backward with the arm outstretched, as in the case of the executive closing the door, or by the pulling forward of the arm by the wash boiler, or swinging of an ax, the conoid ligament is stretched. In the sudden push on the arm and scapula of the football star, or in a fall on the shoulder with arm at the side or arms outstretched in scarecrow position, the trapezoid ligament is stretched. In pushing with both arms forward the strain is on both ligaments.

Our digression has taken us through the evolution of the band, the coracoclavicular ligaments, the function of these ligaments and their relation to the minor injuries. But we have as yet failed to show the important part these ligaments play in acromioclavicular dislocation. Every dislocation of the acromioclavicular joint carries with it an associated injury to the coracoclavicular ligaments. At times the indication of injury to the coracoclavicular joint and its extent is properly gauged by the extent of separation of the acromion and the clavicle. But sometimes the clavicle may be spontaneously reduced to its nor-

mal position or to almost normal position, thus masking the extent of the injury to the coracoclavicular ligaments. It is therefore well to *x*-ray the patient in the standing or sitting position while he is holding a 35 pound weight in each hand, before a negative report of injury to coracoclavicular ligaments is rendered. (Fig. 6.)

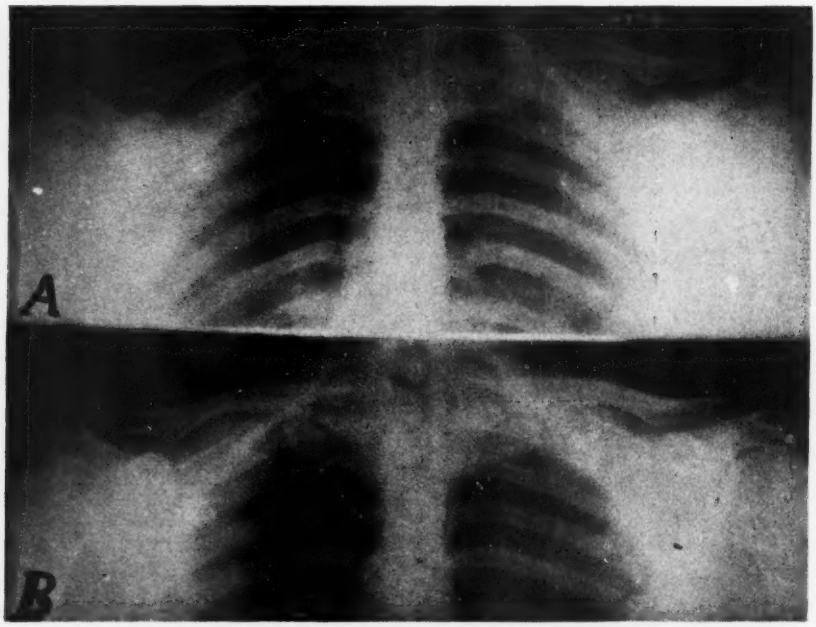

FIG. 6. View of both shoulders of a normal adult in standing position. A, in weight-bearing position (35 pounds of lead in each hand); B, non-weight-bearing position.

Note that the width of coracoclavicular space is greater above and the superior vertebral borders of both scapulae (touched up) are slightly lower with reference to the clavicles in the weight-bearing than in the non-weight-bearing position.

There is one more point I desire to stress here before returning to the clinical material—that in the repair of the coracoclavicular ligaments the surgeon must pay particular attention to the direction of these bands and try to reconstruct as much as possible the direction and tension of the fascia or other material used in reconstruction so as not to allow too much space between the clavicle and coracoid (8 to 10 mm.) and in that way weaken the stabilizing influence of the coracoclavicular ligaments. On the other hand, they should not be made too tight, for this diminishes the flexibility and ease of the movements of the shoulder girdle. The reconstruction of the ligaments aims at stabilizing the scapula on the clavicle, and unless the operation has done it, it is entirely unjustified.

III

From the *x*-ray viewpoint, the clinical material may be grouped so far under two main headings with subgroupings:

1. Injury to the coracoclavicular ligaments without dislocation of the acromioclavicular joint:
   (*a*) Simple sprain of the coracoclavicular ligaments, either conoid or trapezoid, or both.
   (*b*) Tearing of conoid or trapezoid ligaments, seen by *x*-ray in weight-bearing position.
2. Injury to the coracoclavicular ligaments with associated acromioclavicular dislocation:
   (*a*) The acromioclavicular dislocation was reduced spontaneously; the coracoclavicular ligaments never healed, or healed by calcification.

(*b*) The acromioclavicular joint was reduced surgically and held by either sutures, wires, or fascia, but the coracoclavicular ligaments were ignored in the operation.

(*c*) Coracoclavicular ligaments were repaired surgically but for some reason the operative repair did not stabilize the scapula on the clavicle (too much space).

1*a*. *Simple Sprain of the Coracoclavicular Ligaments.* (Example: Executive with door-knob and woman with wash boiler.) This condition usually results from an overstretching of the arm in the scarecrow position, or sudden tension during weight bearing in the forward postion. The patient is unable to use the arm to its fullest extent. There is restriction towards the end of every type of movement. Passive motion will complete the movements without discomfort. There are usually two points which are more sensitive than the other parts of the shoulder; one is the tip of the coracoid which is more sensitive than its mate, the other point is at the middle of the superior border of the scapula.

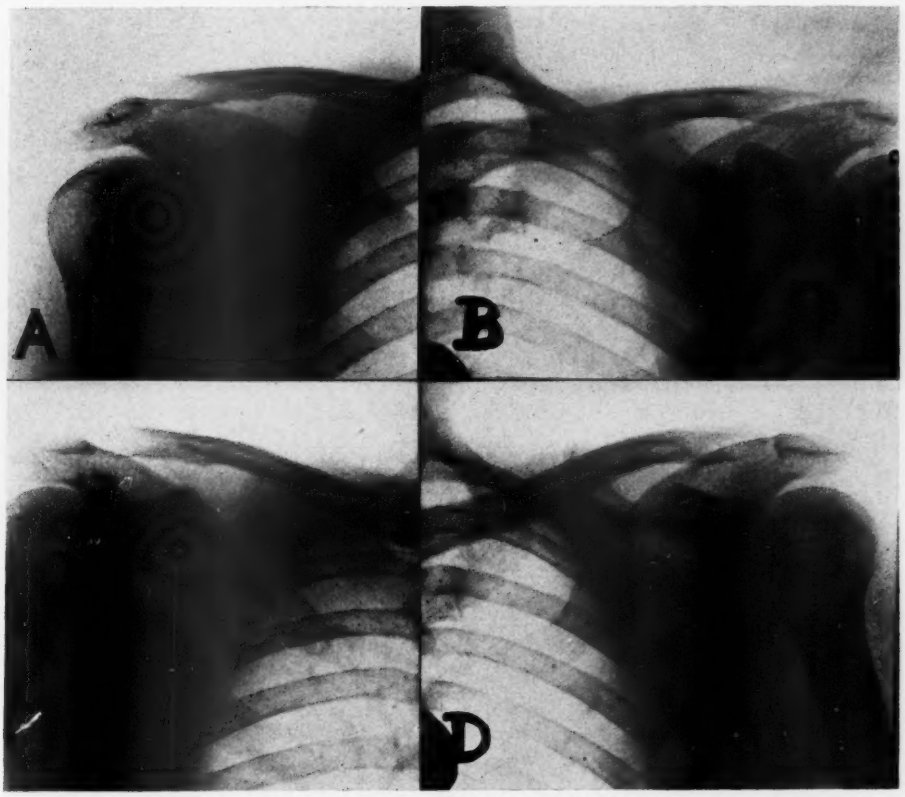

Fig. 7. View of both shoulders of a woman (M. L., age 36) who sustained an injury to the left shoulder as a result of sudden traction of a full wash boiler. A and B, in the weight-bearing position; C and D, without the weights. Note the slightly lower position of the vertebral border of the (normal) right scapula (B) in the weight-bearing as compared with (D) the non-weight-bearing position. The left (sprained) shoulder shows a higher position in the weight-bearing exposure of A, as compared with the non-weight-bearing position (C). Apparently the muscles of the left shoulder are substituting for the coracoclavicular ligaments and overcompensate.

The immediate *x*-ray findings are meager. At times there may be seen slight increased density in the region laterad to the border of the trapezoid ligament; but this region can be visualized only by use of a very fine technique. The *x*-ray examination in the weight-bearing position gives negative or paradoxical findings. (Fig. 7.)

Instead of the upper medial (vertebral) scapular border becoming lower as compared with the non-weight-bearing position a second stage of injury to the coracoclavicular ligaments, and is exemplified by the football star falling on the side,

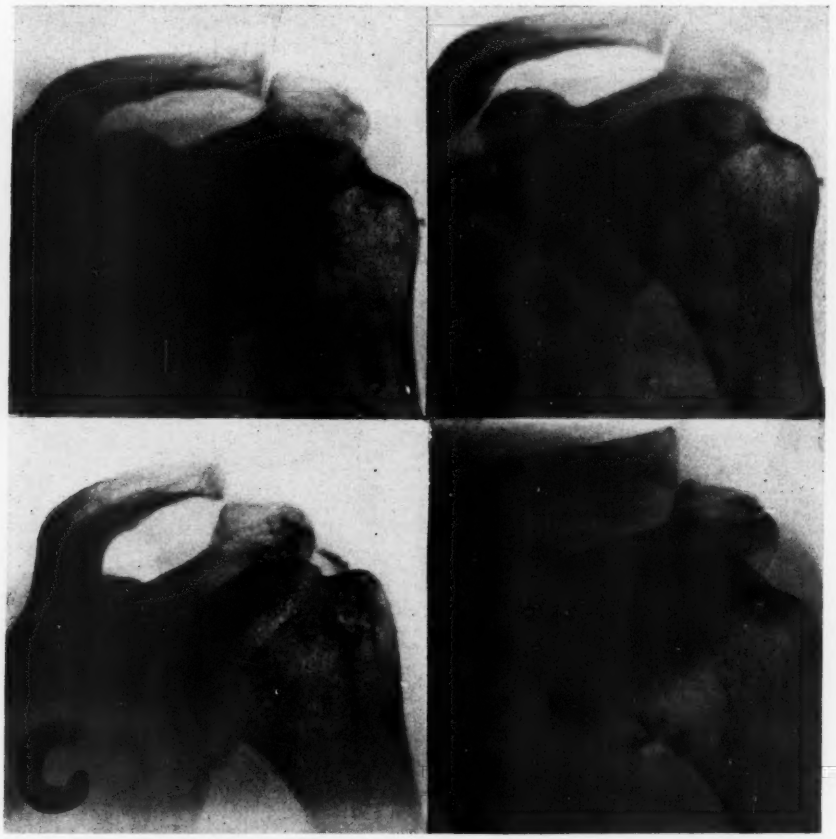

FIG. 8. View of the left shoulder of a male (K. G., age 64). A and B were taken the same day after he was struck by an auto on the left shoulder. They show the position of the clavicle slightly above the level of the acromion but still within upper normal limits. C was taken in the same standing position, but patient held a 35 pound weight in each hand during *x*-ray exposure. It shows the clavicle entirely above the level of the acromion, justifying a diagnosis of torn coracoclavicular ligaments with acromioclavicular dislocation. D, taken nine weeks later. Shows the calcification in the region of the coracoclavicular ligaments, substantiating the former diagnosis of injury to the coracoclavicular ligaments with acromioclavicular dislocation.

it actually appears higher. Apparently the reënforcement of the muscles is greater, due to loss of reliance on the ligaments.

The relief for such conditions has often been accomplished by attempting to bring these ligaments in the most relaxed state, namely the scapula as high and as nearly on line with the clavicle as possible. This is accomplished by a Velpeau bandage or holding the arm in a sling in front of the chest.[5]

1*b. Tearing of Conoid or Trapezoid Ligaments, or Both.* This might be called with the arm in anatomic position. This condition usually results from stretching of the ligaments to a point of actual tearing. Here there is greater limitation and restriction in the use of the arm to its fullest extent than in simple sprain. There is restriction in the beginning and end movements, especially with lifting weights or pushing weight. Pulling on the arm may elicit a "catch" (a point in movement of quick passing pain but not sharp pain, which rapidly disappears when the point is passed). The two points of tenderness are

also present* as frequently as in simple sprain, namely: a point of tenderness over the superior border of the middle of the

The relief of this condition is the same as for sprain. My personal experience in following these cases makes me think that

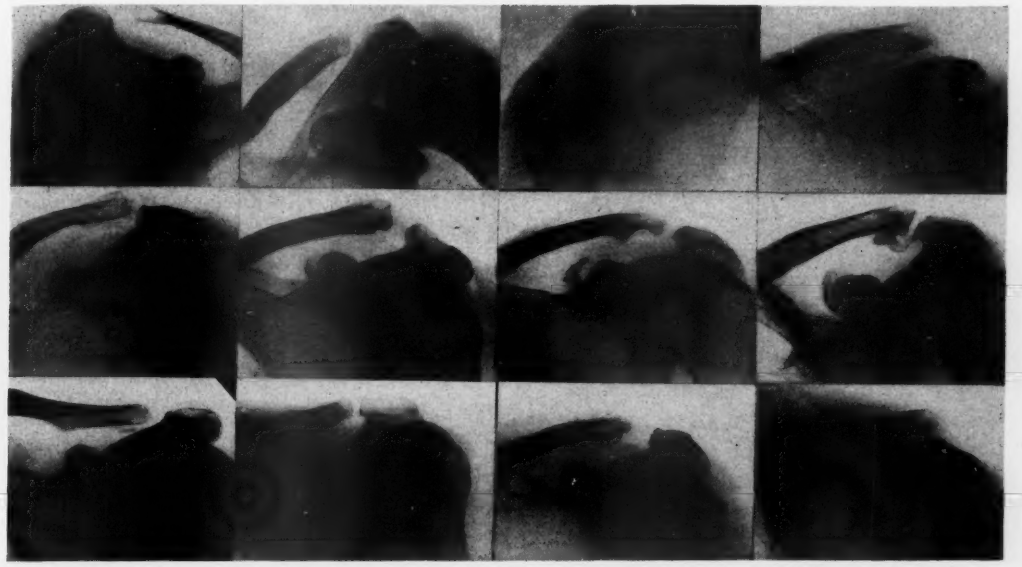

Fig. 9. After-effects of tearing of the coracoclavicular ligaments associated with acromioclavicular dislocation without any medical attention. The cases are arranged according to length of time from the injury to the *x*-ray examination. The first column on the left (three cases) within one month after injury: second within three months: third within nine months: and fourth over one year after injury. All these patients had some difficulty in lifting weights, or on prolonged pushing of hand truck or in pulling a rope.

Note that the greatest calcification at the base of the coracoid (middle row horizontal) is in those cases which have the greatest widening of the space between the coracoid and the clavicle, evidencing greatest injury to the conoid ligaments. In the other cases the greatest calcification is nearest to the dislocated acromioclavicular joint.

scapula and over the coracoid (more than its mate). The immediate *x*-ray findings are negative. Even after injection of air at the site of the ligaments the condition cannot be ascertained because of the great anatomic variation in size and thickness of the ligaments. However, when the *x*-ray exposures are made in the weight-bearing position and compared with the non-weight-bearing, the affected side shows a greater widening of the coracoclavicular space and greater lowering of the upper inner (vertebral) border of the scapula on the clavicle. (Fig. 8.) Superimposing the weight-bearing on the non-weight-bearing exposure facilitates recognition of the width of the space between the coracoid and the clavicle and tends to crystallize the findings.

* The number of cases is not sufficient for statistical study.

if the condition is not improved in two weeks, surgical repair might be advisable in order to avoid the excess of calcium or other solid tissue deposit in the region of the torn ligament, which interferes with smooth and proper function of the shoulder girdle. This view, however, is not favored by one of the leading orthopedic surgeons in this city.

2a. Spontaneous Reduction of Acromioclavicular Dislocation. These injuries are usually similar to those of the last group. They are more often associated with a fall, the arm being in a position to resist the fall, and not in the anatomic position. Or it may follow a blow by a heavy object on the lateral border of the shoulder, not directly inward but slightly downward and inward, the force being greater on the scapula than on the humerus. It also occurs when a heavy weight is lifted by a group of men

(such as the lifting of a crate by four men) and the crate is accidentally released on one side by two men, which results in a sudden pull on the coraco-clavicular ligaments of the other two and sometimes even on the supraspinatus tendon if the weight is very heavy. The same condition results in athletes on sudden striking the horizontal bar.

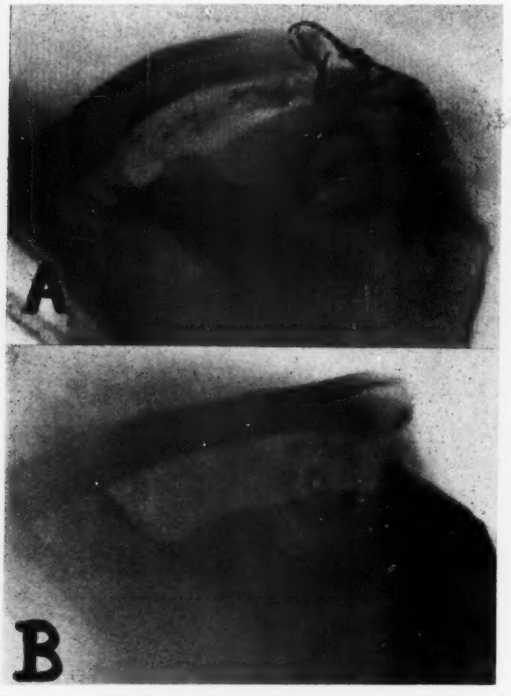

Fig. 10. End results of improper repair of acromioclavicular dislocation because of faulty conception of the underlying pathology. A, a longshoreman who sustained a dislocation of the acromioclavicular joint with tearing of the coracoclavicular ligaments. An immediate open reduction was done, with insertion of two wire loops through the acromion and the clavicle for retention. After a period of about three months, the patient returned to his usual duties and the same day broke both loops of wire and was again disabled. B, a similar case in which non-opaque suture material was used. Note the greater displacement of the lower clavicle as compared with the upper; apparently the wire loops were still serving some purpose on account of inflexibility while the suture material used in the case of the lower figure was flexible and as soon as it tore it pulled out of the holes and the dislocation was again complete.

In fact, any condition which tends to separate the ligaments by force, as in the case of an athlete suddenly striking the horizontal bar, produces the same injury. If the force is too great, however, the ligaments are torn. There is restriction and pain on movement, especially on lifting and pushing. On physical examination there is a drooping of the shoulder and prominence of the acromial end of the clavicle which disappears on raising the arm passively. Abduction is limited by pain. The *x*-ray findings are: high position of the clavicle above the acromion, and marked increase in the space between the coracoid and the clavicle. In cases with incomplete dislocation, *x*-rays taken in weight-bearing state and in non-weight-bearing state will disclose the extent of

Fig. 11. G. C., male, age 50. Injured as result of a fall of one end of a 600 pound pipe (which pinned patient to floor) resulting in dislocation of acromioclavicular joint and tearing of the coracoclavicular ligaments. Operation was done at one of the leading hospitals in New York. Fascia lata from the right iliotibial tract was used around the clavicle and coracoid; rope silk stay suture was looped through drill-holes in acromion and clavicle; Stimson dressing was applied. Patient was discharged on eighth day.

A, five weeks after operation, patient incapacitated for duty. Note slight calcification in the conoid and trapezoid ligaments and moderate separation between the coracoid and clavicle. B, eight months later. Note two calcified areas, one in the region of the torn conoid and the other in the region of the torn trapezoid ligament. Space between coracoid and clavicle still widened and patient was still incapacitated for his duties as longshoreman.

the injury; namely, a higher position of the clavicle above the acromion, low position of the upper inner border of the scapula and marked separation between the coracoid and clavicle. In young patients the dislocation is associated with incomplete tearing of the conoid and trapezoid ligaments. In older people, above the age of 35, when the dislocation of the acromioclavicular joint is complete there is usually complete tearing of the conoid and trapezoid ligaments. The *x*-ray films taken in the weight-bearing position usually disclose the extent of the injury and indicates the necessity of radical therapeutic measures. The relief of this condition is usually obtained by means of a Velpeau bandage, adhesive strapping, or a plaster jacket. More often, he is left alone and we find the end results of this form of treatment. (Fig. 9.)

The relief, although sufficient to reduce the dislocated acromioclavicular joint, does not favor the repair of the torn coracoclavicular ligaments. As a rule the patient is discharged six weeks after the injury as "cured" but he still has a weakened shoulder. This is the end result of inadequate therapy for the dislocation of the acromioclavicular joint with tearing of the conoid and trapezoid ligaments.

2b. Surgical Reduction of Acromioclavicular Joint. This group of acromioclavicular joint injuries is separated from the others by the fact that the cases although properly diagnosed at the very beginning clinically and substantiated by *x*-ray, the surgical repair undertaken was unsuccessful. The surgeon, unaware of the leading rôle played by the torn coracoclavicular ligaments in the dislocation of the acromioclavicular joint, performed an open reduction on the acromioclavicular joint by placing one or two sutures or loops of wire through the acromion and the clavicle, ignoring the associated injury to the coracoclavicular ligament. After a period during which the soft tissues have receded and the infiltration absorbed, patients return to their duties only to find limitation in motion. They are unable to push or pull with the arm, and quite often on the first effort of traction or pushing, the splinting material (wire, kangaroo tendon or fascial sheath) breaks. They then return to the clinic with a recurrent dislocation. (Fig. 10.) It is evident from what has been said so far that the important structures which the surgeon failed

DOUBLE FIGURE EIGHT TYPE OF RECONSTRUCTION OF THE CORACO-CLAVICULAR LIGAMENTS.

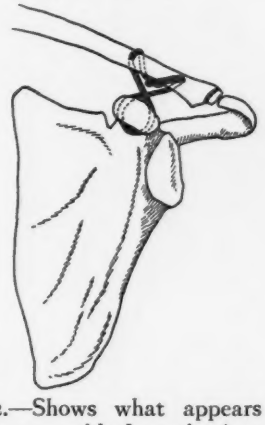

Fig. 12.—Shows what appears to the author as an ideal repair. A curved incision over the clavicle from the acromion to the inner third; two drill-holes through the vertical diameter of the clavicle 1 and 2 inches from the end respectively. A strip of fascia 7 inches long, doubled, is first threaded through the outer hole of the clavicle from above downward. A pair of curved artery clamps is inserted under the coracoid, directing the clamps from the outer border inward, between the muscle attachment (coracobrachialis pectoralis minor biceps) and the base of the coracoid. The fascial sheath is now pulled over the inner part of the coracoid and fed into the jaws of the clamp. The clamp is slowly withdrawn until the jaws clear the coracoid; then the clamp jaws are pushed above the coracoid. From there the fascial sheath is threaded into the inner hole of the clavicle from below. The ends are then brought together, the outer end from in front above and the inner end from the back to the undersurface of the clavicle sutured. Care must be taken to bring the scapula as close as possible to the clavicle by manipulating the arm before the ends of the fascial sheath are sutured. A supplementary suture between the acromion and the clavicle for stabilization would be in place for greater security.

to reckon with are the coracoclavicular ligaments.

2c. Operative Repair of Coracoclavicular Ligaments. There is another group of acromioclavicular dislocation in which operation has been performed. However, in repairing the acromioclaviuclar ligaments, the surgeon has made the reconstructed ligaments too long (or, rarely, too short). (Fig. 11.) In either case he has not given the patient a restoration but only a substitution. If the surgeon is careful in reconstructing the coracoclavicular bands so that they extend from the posterior external part of the clavicle to the anterior internal part of the coracoid and from the external part of the coracoid to the anterior part of the clavicle, arched around the neck of the coracoid and part of the clavicle, with not more than ⅜ inch or less than ¼ inch separation between the coracoid and the clavicle, he will then avoid the pitfalls of improper repair. (Fig. 12.)

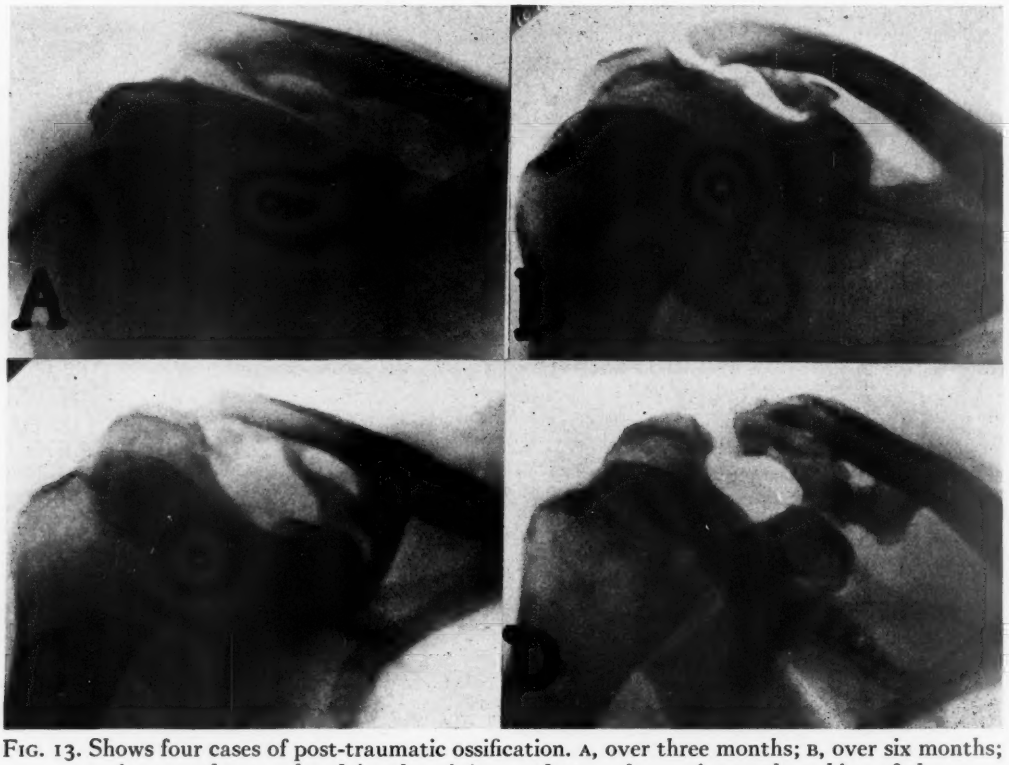

Fig. 13. Shows four cases of post-traumatic ossification. A, over three months; B, over six months; C, over nine months; D, who claimed an injury only two days prior to the taking of the *x*-ray and denied any previous injury. The ossification in the clavicular part of the conoid and trapezoid was by its texture interpreted to be at least one year's duration. Note in C the complete ossification of the conoid and trapezoid ligaments particularly at the coracoid, while in D the ossification is further advanced yet not as complete. All four patients claimed greater tiredness in the affected shoulder than in the other although most of the pulling and pushing was done with the other. There was limitation in abduction; especially above the horizontal, and general sluggishness on movement in the affected shoulders as compared with the normal shoulders.

This arrangement of a fascial band makes a figure eight, starting from a drillhole at the outer posterior part of the clavicle, about 1 inch from the acromion from above, winding around the inner part of the coracoid neck to the outer part of the coracoid. From here it goes to the inner anterior under surface of the clavicle through a drillhole 1 inch from the former, through the clavicle upward. It is then carried over the top to the front of the clavicle and joined to the other end of the band at the outer end of the clavicle beneath. In such a reconstruction there will be much less postoperative ossification and a weakened and painful state of the shoulder can be avoided.

The post-traumatic ossification of the ligaments, resulting either from injury to the coracoclavicular ligaments or from improper attention to the acromioclavicular dislocation with injury to the ligaments, causes considerable hardship and disturbed function of the shoulder girdle and I know of no procedure to alleviate it. (Fig. 13.)

SUMMARY

One thousand eight hundred Roentgen examinations of the shoulders of patients in the Out-Patient Service at U. S. Marine Hospital, New York, whose chief complaint was pain, were reviewed. Thirty-six patients showed local pathology of the coracoclavicular ligament. Of these, nine patients had a coracoclavicular joint, in five of which the joint was bilateral.

The important rôle of the coracoclavicular ligaments play in stabilizing the shoulder girdle, their evolutional and anatomic analogy to the crucial ligaments of the knee joint, are pointed out.

The movements of the scapula on the clavicle in each of the three planes and the extent and limits of these movements by the coracoclavicular ligaments are analyzed and illustrated. The important rôle the coracoclavicular ligaments play in sprains of the shoulder is illustrated by case reports. A method for the *x*-ray demonstration of severe injuries to these ligaments is introduced.

A clinico-roentgenologic division of the cases into two major groups is made, and the subgroups are illustrated by case reports.

An appeal is made for better evaluation of the importance of the coracoclavicular ligaments in acromioclavicular dislocations.

I wish to express my gratitude to Senior Surgeon J. Bolten for his kind coöperation, and to Miss Beatrice James, Winthrop D. Conklin and Hyman Vozick, for their untiring coöperation.

REFERENCES

1. King, J. M., Jr., and Holmes, S. W. Review of 450 Roentgen ray examinations of the shoulder. *Am. J. Roentgenol.*, 17: 214–218, 1927.
2. Leniez. Etude anatomique pour servir à l'évaluation du dégré d'invalidité dans les traumatismes de la ceinture scapulo-thoracique. *Vie méd.*, 16: 115–123 (Feb. 10) 1935.
3. Huntington, G. S. Modern problems of evolution, variation, and inheritance in the anatomical part of the medical curriculum. *Anat. Rec.*, 14: 395, 1918.
4. Cunningham's Text Book of Anatomy, 5th ed. Pp. 319 and 322. New York, 1918. Wm. Wood.
5. Key, J. A., and Conwell, H. E. Fractures, Dislocations and Sprains, 2nd ed., p. 456. St. Louis, 1937. C. V. Mosby.

CHRONIC SPRAINED ANKLE

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CHRONIC sprained ankle is the result of either (1) an acute sprain that has not been given an opportunity to recover before it is subjected to normal use; or (2) one which has an inherent weakness associated with some imbalance of the foot, being subjected to constant stress through daily usage. An acute sprained ankle has both intra- and extra-articular manifestations, e.g., synovitis is intra-articular, whereas swelling and discoloration are extra-articular, due to the tearing of one or more vessels coursing between the skin and the ligaments with consequent extravasation of blood. This latter explains the diffused subcuticular discolorations.

An acute sprain may be one of three types, which are, in order of frequency and importance: (1) A simple overstress on the ligaments may occur, more often on the lateral than on the medial aspects. Occasionally, the anterior ligaments may be involved due to sudden plantar flexion and rarely the posterior group because of sudden hyperdorsal flexion. (2) Stress may develop upon the ligaments, accompanied by tearing of the periosteal attachment, more often of the anterior fasciculus of the external lateral ligament at its attachment either to the external malleolus or to the astragalus. (3) There may be a tearing of the lateral ligament, again more often of the anterior fasciculus. I have never seen a case of tearing of the lateral ligaments that was not complicated by dislocation or fracture in its early stages. I have, however, seen two which, several years after the injury, showed definite evidence of tearing of this portion of the ligament, without a history of either dislocation or fracture.

The symptoms of acute sprained ankle need no description, but the symptoms of chronic sprained ankle are so frequently misinterpreted that they do need exemplification. They are, in the first group, no swelling, no discoloration, freedom of motion except in adduction. The latter causes a slight complaint of pain which seems to be the limiting factor rather than any mechanical cause. There is often a complaint of vague pain in the ankle at all times, but the patients can do nothing more than point to the outer side of the ankle as the area involved. It is here that a knowledge of the attachment of the anterior fasciculus is absolutely necessary to the diagnosis. One adducts the foot and palpates lightly the anterior edge of the malleolus. The patient will immediately wince. If this sign fails, palpation over the astragalus at the site of attachment will cause complaint. In some instances, the tenderness is present at both sites. One need not try to recognize tenderness with the foot in a normal position—adduction is absolutely necessary. The explanation for this localizing tenderness and resulting discomfort lies in the stress that has been brought upon the attachment of the ligament to the periosteum resulting in a chronic periostitis which will not show in the *x*-ray.

In the case of actual tearing of the ligaments, one may find the tenderness at either site but there is something that is far more striking, i.e., loss of normal contour in the course of the ligament. The normal contour is replaced by a deep indentation which, when palpated, fails to show the normal resistance imparted by the anterior ligament.

In all these cases one finds an associated weak foot, with resultant misdiagnosis. The usual supportive treatment for weak feet fails, however, to solve this problem.

In the treatment of Type 1, immediate balancing of the foot by the use of a 3/16 inner heel wedge plus a 1/8 outer sole wedge is the first essential. One must remember that the inner heel wedge is not a panacea as is commonly believed, that many feet show a pronation of the heel with a varus of the forefoot. When one puts a wedge on the inner side of the heel it corrects the pronation of the heel but makes the varus of the forefoot worse, thereby increasing the imbalance instead of improving it. The use of the outer sole wedge will turn the forefoot at the mediotarsal articulation in such a way as to restore normal balance. This simple measure has been most satisfactory in the treatment of those patients who constantly turn their ankles. They have a tendency, figuratively speaking, to trip over the "flowers in the rug." Their ankles turn without apparent cause.

These corrections should never be placed in a heel which is higher than 1 4/8. In fact, the ideal heel should be either 1 0/8 or 1 2/8 in height, unless the tendo Achillis is so short that the heel height gives rise to marked discomfort.

If these cases are seen early, one may make a half-moon of felt whose concavity corresponds with the shape of the malleolus, and then apply a Gibney boot or a modification thereof to hold the felt in place. This, with the corrective shoes, frequently is all that is necessary.

However, if the case is an old one, ionization is recommended, with tincture of iodine over the affected area and employment of the negative pole of the Galvanic current. Either a spongiopiline electrode or a flat metal one wrapped in absorbent cotton may be used, but either should be wet with normal salt solution. If drying occurs during treatment, moisten the electrode as frequently as indicated. The positive pole is placed in any convenient position and the current regulated to suit the comfort of the patient. If a battery is not at hand, indirect diathermy, but never direct, may be used. Short wave therapy has not given results in our experience. When there is no electrical apparatus, the use of local heat followed by massage with iodine ointment, mercurial ointment or methyl salicylate, 1 dram in lanolin to make 1 ounce, gives satisfactory results. Novocaine or other substance used by injection for localized pain has not proved of any value.

The second type of chronic sprained ankle is often referred to by its possessor as a swollen or fat ankle. The most annoying symptom is an enlargement about the external malleolus which swells at night and goes down in the morning. It usually overhangs the top of a low-cut shoe and is sometimes tender; however, as a rule, the chief complaint is the disfigurement. These swellings vary greatly in size from a small rounded mass the size of a plum to one which may be as large as half an orange. Upon close examination, they are found to be readily picked up with the fingers and moved over the underlying tissue. They usually lie in front and below the malleolus, but occasionally, the larger ones show a prolongation posteriorly to the malleolus. The fact that they are movable differentiates them at once from the common swollen ankle of injury or constitutional disease. They are semisolid in consistency and at times, if the skin is thin, definite lobulation can be found. These swellings are lipomata that have resulted from one severe or several minor ankle sprains where there has been hemorrhagic effusion with incomplete absorption. They are rarely, if ever, seen in individuals who have a well-balanced foot although they may occur in these people following a severe sprained ankle with customary effusion of blood.

When pain is complained of, it is due to the same causes as in Type 1.

A third type of chronic sprained ankle is sometimes seen. Here there has been definite ligamentous tear, and instead of

enlargement and tumor growth, there is indentation. We have found one or two rather aberrant cases following severe ankle sprains where the condition has been more anterior than lateral. There has been exostotic development on the anterior part of the astragulus in such a position as definitely to block the dorsal flexion of the foot by impinging upon the anterior face of the tibia. In both cases the growth could easily be felt beneath the tendons. *X*-rays have proved the diagnosis and removal has brought about cure.

When the lipoma exists there is but one method of treatment, that is, operative removal. The operation is simple, but in thin-skinned individuals there is frequently trouble in skin healing. The tendency is for the edges to spread or at times to slough, giving rise to a disfiguring scar. I have tried various types of incisions about and over these growths but so far have not found one in which the edges will never slough. It is peculiar, however, that most women seem to prefer a disfiguring scar to the lipomata. If operation is refused, improvement is obtained in some cases by a corrective shoe which is well-balanced, and which has a low-cut upper on the side where the lipoma is present. The higher the upper the more likely it is to throw the growth into relief unless a regular shoe with a top be worn, but with present style tendencies, a shoe with a top seems to attract far more attention than the swelling.

So far we have found no satisfactory solution to the cases in which the ligament has been torn years before. The best we can do with these is to apply the treatment for sprained ankle with periostitis. So far we have not attempted to repair the ligaments with fascia transplants. We question whether the operative procedure with the resulting scarring and the possibility of failure is not a worse cure than the disease for which it would be proposed.

SUMMARY

1. The common findings in chronic sprained ankle have been discussed.

2. We have attempted to point out the cause for many misdiagnosed cases of pain about the ankle joint.

3. Treatment which has been satisfactory in our hands has been suggested.

CARDIOVASCULAR COMPLICATIONS OF FRACTURE*

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CARDIOVASCULAR complications are directly or indirectly responsible for the great majority of deaths incident to fractures in elderly persons. In addition, manifestations of cardiac disorder are frequent during the convalescent stage of fracture and sometimes for an indefinite period thereafter. The important influence which fractures may exert upon the cardiovascular system is emphasized by these facts and is the subject of the following study.

The records of 500 successive cases of simple fracture from the wards of the Philadelphia General Hospital were analyzed with respect to location of the fracture, age of the patient, nature of any cardiovascular complications and mode of death. The series included fractures in all parts of the body except the skull, because the latter involves complications which are essentially neurologic. The patients were of both sexes and ranged in age from 15 to 92 years.

RESULTS

Mortality According to Age. From Table 1 it is seen that the incidence of death among hospitalized fracture cases is conspicuously associated with advanced age. The mortality among all patients under 60 years of age was less than 2 per cent. Of the patients in the seventh decade, however, approximately one-fifth died, in the eighth decade, one-third died, and in the ninth decade and older, over one-half died.

The Relationship of Associated Cardiovascular Disease to Mortality. In persons over 60 years of age, the cardiovascular system is invariably the site of some degree of degenerative change. Such change is due partly to the physiologic aging process of man and partly to a disorder which has been regarded as metabolic in nature and of which atheromatosis is a manifestation.[1] This factor is apparently the predisposing cause of the common type of death in elderly fracture patients.[2] Under the circumstances, it seemed justifiable to include all patients in this series who were over 60 years of age in the group which had associated (arteriosclerotic) cardiovascular disease.

TABLE 1

MORTALITY ACCORDING TO AGE IN 500 CASES OF FRACTURE

Simple fractures of all types except fractured skull admitted to Philadelphia General Hospital

	No. of Cases	Deaths	Per Cent Mortality
	500	82	16
Over 80 years	42	22	52
70 to 79 years	91	32	35
60 to 69 years	82	19	23
Under 60 years	285	5	2

Table 11 indicates that among the total 500 cases of fracture, the mortality was 16 per cent. In 230 with associated cardiovascular disease there was a mortality of 34 per cent, while in the remaining 270 cases with no apparent cardiovascular disease the mortality was only slightly over 1 per cent. The presence of cardiovascular disease, therefore, increases the likelihood of a fatal outcome by approximately thirty times.

Types of Heart Disease Complicating Fracture. The apparent type and extent

* Read before the Annual Meeting of the Interurban Orthopedic Club, Philadelphia, October 7, 1938.

TABLE II
INCIDENCE OF CARDIOVASCULAR COMPLICATIONS IN 500 CASES OF FRACTURE

	No. of Cases	Deaths	Per Cent Mortality
No associated cardiovascular disease	270	3	1
Associated cardiovascular disease; all ages	230	79	34
Associated cardiovascular disease; over 60 years	215	77	36
Associated cardiovascular disease; under 60 years	15	2	13

of the myocardial change as judged by the recorded murmurs, heart size and electrocardiogram showed surprisingly little correlation with the incidence of death, although this fact could not be evaluated statistically because of the lack of sufficient detail in the average cardiovascular examination of patients on large surgical services.

TABLE III
TYPES OF CARDIOVASCULAR DISEASE ASSOCIATED WITH 500 CASES OF FRACTURE, ALL AGES

	No. of Cases	Deaths	Per Cent Mortality
Arteriosclerosis; over 60 years old, with or without hypertension	215	77	36
Hypertension; under 60 years old, with or without arteriosclerosis	12	2	17
Rheumatic heart disease	1	0	0
Syphilitic heart disease	1	0	0
Phlebitis	1	0	0

Table III shows that the mortality was highest among patients who had arteriosclerotic cardiovascular disease either with or without hypertension. Of such cases, approximately one-third were fatal. Among patients who had hypertension and relatively little obvious arteriosclerosis, the mortality was one-half that of the preceding group. Only two patients in the entire series had other types of heart disease; one was rheumatic, the other syphilitic; both recovered.

Types of Fracture Complicated by Cardiovascular Disease. In 72 of the fatal cases complicated by cardiovascular disease, the fracture involved the upper end of the femur and in most instances was intertrochanteric. In two cases the site of the fracture was the lower part of the femur, in two others, the tibia, and in one case each, the pelvis, humerus and clavicle. The hip is therefore the outstanding site of fatal fractures.

TABLE IV
TYPES OF FRACTURE PRESENT IN 79 FATAL CASES COMPLICATED BY CARDIOVASCULAR DISEASE

	No. of Cases
Upper femur (mostly intertrochanteric)	72
Lower femur	2
Tibia	2
Pelvis	1
Humerus	1
Clavicle	1

Mode of Death. On the clinical records, numerous different diagnoses were used to explain the occurrence of death among patients who had associated cardiovascular disease. These included arteriosclerotic heart disease, hypertension, bronchopneumonia, uremia, infection and other conditions. However, the mode of death in almost all cases was strikingly similar, as were also the pathologic changes.

The common pathologic feature on postmortem examination in the great majority of cases consisted of generalized passive congestion, particularly of the lungs and abdominal viscera, with little or no clinical edema. Some patients had various degrees of bronchopneumonia. Except for cases of longstanding hypertension, few had any significant enlargement of the heart such as occurs in congestive heart failure. Evidence of recent myocardial infarction was also unusual although coronary sclerosis and myocardial fibrosis were rather consistently present.

The common clinical feature of these cases was gradual and progressive weakness

accompanied to a variable degree by mental deterioration, renal insufficiency, hypostatic pulmonary congestion and terminal bronchopneumonia. Death of this type occurring in elderly patients has been attributed to diminution of venous return flow to the heart due to physical inertia.[2] The underlying pathologic fault is apparently the sclerosis of the peripheral arterioles, the effect of which is to permit blood to remain in the venules. Stasis of blood in the periphery produces anoxia and increased permeability of the capillaries with loss of fluid into the tissues and decrease in circulating blood volume. If death occurs, it may take the form of renal insufficiency, infection or cardiac failure, but such events represent simply the terminal episodes.

DISCUSSION

The Effects of Fractures on the Cardiovascular System. Analysis of the 500 cases of fracture here presented indicates that the mortality in such cases is, with only a few exceptions, associated with the presence of arteriosclerotic cardiovascular disease and to a lesser extent, with hypertension. Death results from a type of peripheral circulatory failure described above, the mechanism of which closely resembles that of shock. It is for the most part a slow process which becomes conspicuous only after one or two weeks in bed, generally for a fractured hip, less often for other confining fractures. Confinement to bed with its consequent physical immobility is thus the most important manner by which fractures may exert a deleterious or even fatal effect upon the cardiovascular system. In the absence of arteriosclerosis, i.e., in the younger age groups, this effect is probably seldom if ever serious.

Of the other ways in which the cardiovascular system may be adversely affected by fracture, the next in importance is acute shock. The effect of acute shock is to produce a sudden decrease in the volume of circulating blood with a resultant generalized vasoconstriction, a tendency to pulmonary edema and a decrease in the coronary circulation. In almost any case of heart disease, irrespective of type, in which the patient is bordering on congestive failure, such an event is obviously serious since it temporarily disturbs whatever compensatory mechanism has been established to prevent circulatory collapse. Areas of the myocardium which happen to be supplied by sclerosed coronary vessels may suffer from acute anoxia and actual infarction may result. Severe pulmonary edema is often precipitated. Serious arhythmias may develop as a consequence of myocardial ischemia, direct nervous influences and the compensatory secretion of adrenalin.

Fractures may also affect the heart and circulation through the influence of pain. This factor is, of course, extremely difficult to evaluate but is nonetheless real. The effect of pain on the circulation is variable; moderate pain usually accelerates the heart rate and raises blood pressure while severe or long-continued pain may slow the heart rate and lower the blood pressure. As a rule, body metabolism is accelerated, the work of the heart increased and adequate rest may be prevented. Such disturbances are obviously capable of precipitating heart failure in persons suffering from various forms of myocardial impairment. Further potential effects include disorders of endocrine function such as the occasional precipitation of a thyroid crisis or even a pituitary syndrome.[3]

Not infrequently it is found that elderly persons who have sustained a fracture, especially one involving prolonged convalescence and considerable discomfort, suffer continuously thereafter from easy fatigue, breathlessness and vague precordial pains. The precise nature of what has taken place in the body to produce such an effect is often difficult to explain since no organic changes in the cardiovascular system are apparent. It is as if the patient has grown much older in a short period of time. Psychologic factors, especially pain and consciousness of any

residual disability due to the fracture, undoubtedly play a large part in many of these cases. In addition, however, it seems reasonable to presume that in some way tissue metabolism has been disturbed so that muscular movement is less efficiently performed and a greater strain is thereby placed upon the cardiovascular system. Very likely it is this added strain, rather than any structural damage to the circulatory apparatus, which in the majority of instances produces the cardiac symptoms. The condition is perhaps comparable to being "out of training" and the patient may never succeed in fully readjusting himself.

During the convalescent stage of fracture the appearance of cardiac arhythmias is quite common. Usually they consist of extrasystoles, but auricular fibrillation or paroxysmal tachycardia are often observed as transient episodes, less frequently persistent. Ordinarily these complications are not serious, yet they may be very serious in the presence of advanced organic heart disease, particularly coronary sclerosis. In the latter cases they may cause anginal attacks or even precipitate sudden death if the heart is unable to tolerate the sudden excessive activity. These arhythmias may appear immediately after the fracture or they may develop several days or even weeks later. The way in which they are produced by a fracture is a matter of speculation, but their disappearance after healing of the lesion leaves no doubt as to the certainty of a causal relationship.

Direct trauma of the heart should never be overlooked as a possible complication of fractured ribs, more particularly in the case of "steering wheel fractures." Cardiac damage is not always very obvious on examination, especially if the patient is in shock. Tears of the pericardium or rupture of pericardial or epicardial vessels may produce hemopericardium which is sometimes unnoticed until several hours after its onset, at which time the patient suddenly collapses. More often, however, the cardiac damage consists of a traumatic myocarditis which, although it tends to disappear, may give rise to symptoms for years afterward. It is undoubtedly true that the majority of cases of traumatic myocarditis are never diagnosed because of the absence of physical signs and failure to take an electrocardiogram during the acute stage.[4] The patient's cardiac symptoms under the circumstances are attributed to nervousness, pleural irritation or the fractured ribs.

In connection with direct trauma, mention should be made of vascular lesions produced especially by fractures of the bones of the limbs. Occlusion of a main artery of the leg in this manner may result in gangrene, a complication which is particularly unfortunate because it is generally easy to prevent. The application of proper therapeutic measures designed to inhibit peripheral vasoconstrictor tonus of the limb vessels almost always affords sufficient increase in collateral circulation to counteract the immediate and most serious effect of the occlusion. Needless to qualify further is the possibility of seriously obstructing the limb circulation by an improperly fitted cast or splint.

A final complication of fractures which is dramatic but rare is pulmonary embolism. No cases of this type have occurred at the Philadelphia General Hospital during the past five years, which is rather surprising. The majority of pulmonary emboli do not cause death but they are always very serious. They occur occasionally after open reduction of fractures, and more frequently as a result of associated phlebitis, the appearance of which should be regarded as an indication for careful preventive therapy.

SUMMARY AND CONCLUSIONS

Five hundred hospitalized cases of fracture were analyzed with respect to cardiovascular complications. The mortality for the cases having a normal cardiovascular system was 1 per cent; for those having associated cardiovascular disease, 34 per

cent. The vast majority of fracture patients who died had clinical evidence of arteriosclerotic cardiovascular disease and had sustained a broken hip. Death resulted in these cases from a form of slowly progressive peripheral circulatory failure. The various ways in which fractures may cause damage or functional impairment of the cardiovascular system are discussed.

REFERENCES

1. Cowdry, E. V. Arteriosclerosis. New York, 1933. Macmillan.
2. Laplace, L. B., and Nicholson, J. T. Prolonged recumbency as a contributory cause of death in elderly persons. *J. A. M. A.*, 110: 247 (Jan. 22) 1938.
3. Thompson, A. P. The sudden appearance of senility after an accident. *Lancet*, 2: 135 (July 16) 1938.
4. Beck, Claude. Personal communication.

Though there are hundreds of proteins in our foods, they are all combinations of only twenty-two amino acids, each of which is essential to life.

THE TREATMENT OF FRACTURES OF THE PATELLA*

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A FRACTURE of the patella usually involves an interruption of the extensor apparatus of the knee. The objects of treatment are (1) to restore the complete and powerful extension of the knee and (2) to preserve or restore the normal range of flexion without leaving some irregularity of the articular surface which will tend to irritate the joint and lead to the development of a progressive arthritis after function is resumed. In addition to the above, the treatment should be so planned that the patient is subjected to as little risk as possible, that his loss of time from work is as short as possible, and that he is as comfortable as possible during his convalescence.

That the ideal method of treatment has not yet been evolved is evident from the large number described in the literature and at present used by various surgeons. It may be assumed that each of the methods now in use has been found to be satisfactory to some surgeons but not to all. In this paper I shall mention briefly a number of the methods in general use and shall describe the methods which I prefer and state why I prefer them.

In considering the treatment of a recent simple fracture of the patella the first decision required is whether or not an open operation is indicated. This decision is based upon the position of the fragments as determined by the physical examination and the roentgenogram, it being assumed that a competent surgeon and adequate facilities for aseptic surgery are available. The operation appears quite simple, but may easily go wrong and rigid asepsis is necessary because the superficial position of the bone and its relatively poor blood supply seem to render it liable to infection. Should infection occur the knee joint is usually involved and the surgeon faces a surgical catastrophe of considerable magnitude.

Consequently, operative fixation of a fracture of the patella is reserved for those instances in which the fracture consists of, or includes, a complete transverse lesion with the fragments separated for ⅛ inch or more. Experience has shown that such fractures do not tend to unite by bone under conservative treatment and that it matters not whether the fracture is simple transverse, mildly comminuted, or stellate in type. Not only do these fractures not unite by bone, but when there is separation of the fragments the lateral aponeurosis of the knee on either side of the patella is torn and the contraction of the quadriceps tends to pull the proximal fragment of the patella upward and the separation tends to increase with time. This results in a weak and relatively unstable extremity.

TREATMENT OF SIMPLE FRACTURES IN WHICH THE FRAGMENTS ARE NOT SEPARATED

We will first consider the treatment of simple fractures without separation of the fragments. These may be either simple transverse or comminuted, as the number and the direction of the fracture lines apparently make little or no difference in the healing, unless the fragments are separated. As a matter of fact, an extensively comminuted fracture of the patella without separation of the fragments may be expected to unite more promptly than will a simple transverse fracture with a separation of ⅛ inch, because these comminuted fractures are the result of direct violence and as a rule the lateral aponeurosis is not torn.

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In fractures in which it has been decided not to operate it is advisable to aspirate the knee joint and apply a pressure dressing for from twenty-four to forty-eight hours, having the patient remain in bed either with or without a posterior splint. A very efficient form of pressure dressing is one made of a roll of absorbent cotton wrapped around the knee. Over this either a gauze or an elastic bandage is applied tightly. This will tend to prevent further accumulation of blood in the joint. After the excess fluid has been removed and before the pressure dressing is applied, an attempt should be made to mould the fragments by lateral and vertical digital pressure if the roentgenogram has shown slight displacement. Any irregularity of the articular surface is corrected by pressing the patella downward against the condyles of the femur. If at the end of from twenty-four to forty-eight hours there is excess fluid in the joint this should be aspirated a second time.

In aspirating the knee usually no local anesthesia is necessary. An area lateral or mesial to the superior border of the patella is painted with strong tincture of iodine. With a quick stab the needle is plunged into the knee joint, aiming at a point directly beneath the upper portion of the patella. In a hypersensitive or nervous patient the area may be infiltrated with novocaine if desired. As much blood as can be removed is then aspirated, the needle withdrawn, and a piece of sterile gauze placed over the puncture wound. I do not believe that it is necessary, or even advisable, to shave the leg or for the surgeon to scrub his hands or use rubber gloves. There is no need for the surgeon's hands to come in contact with the aspirating needle at any time during the procedure.

After the excess blood in the joint has been removed, a plaster of Paris cast is applied with the knee in a position of extension. This cast is preferably of the skin-tight walking plaster type with a small piece of felt over the patella and a thin layer of cotton around the knee joint in order to provide for the small amount of movement which occurs at the knee. However, if one prefers, the ordinary padded plaster of Paris cast may be used. It should extend from the toes up to the groin, as it is necessary that it include as much of the thigh as possible. One should plan on leaving the cast on about six weeks. Various types of adhesive dressings have been used beneath the plaster in an attempt to bring the patellar fragments together. The usual method is to place oblique cross strips above and below; those above tend to pull the proximal fragment downward and those below tend to pull the distal fragment upward. These strips often irritate the skin beneath the cast and I do not believe they are very effective in holding the fragments together. Consequently, I no longer use them.

At the end of from four to eight weeks, depending on the fracture and the age of the patient, the plaster cast is removed and the patient may begin to bend the knee. It will be found that a relatively small amount of movement will be permitted. However, the knee should not be forced. The patient may apply hot wet compresses or dry heat to the knee two or three times daily and should exercise the quadriceps and begin to walk. At first crutches are used and then a cane; as the power in the leg returns the support is abandoned. For at least four weeks after the removal of the cast the patient is cautioned not to put his weight on the leg with the knee in a position of flexion, but to walk with the knee straight, because not only is the union not firm, but extensive atrophy has occurred in the patella and it can be refractured with relatively slight force. (Fig. 1.)

Union should be quite firm at the end of eight weeks and bony union is usually present at the end of twelve weeks. However, it may not be demonstrable in the *x*-ray for several months. The exercises to restore the power in the quadriceps must be kept up over a period of several months. If union occurs a practically normal knee may

be expected in from four to six months and the patient may be expected to return to occupations not involving heavy lifting or running within about three months.

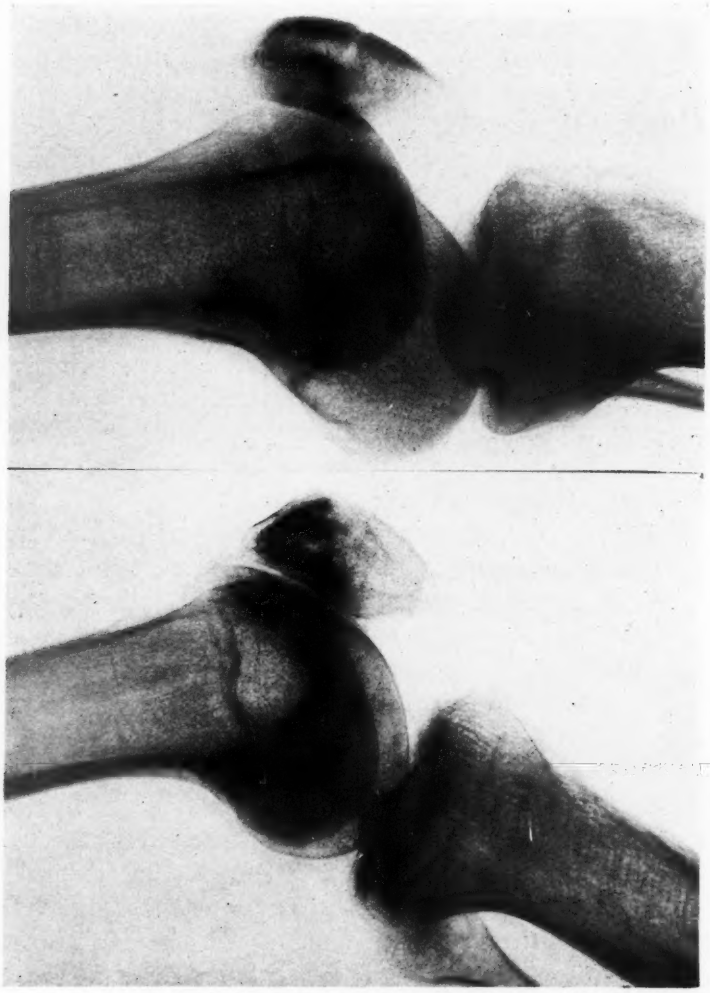


Fig. 1. Above, simple fracture of the patella without displacement. Below, same case two months later after removal of the cast. Note union, but marked atrophy of the bone.

TREATMENT OF SIMPLE FRACTURES OF THE PATELLA WITH SEPARATION OF THE FRAGMENTS

In these fractures operative reduction and fixation of the fragments and operative suture of the lateral aponeurosis is advised. This operation has been done for many years. That there is no method which is universally satisfactory is evidenced by the fact that there are a multitude of methods in use and by the fact that many subcutaneous methods of manipulating the fragments by wires, pins or clamps have been advised and used. I do not believe that any subcutaneous method should be used, because control of asepsis thus becomes more difficult and control of the fragments is less exact.

The first question to decide is—When should one operate? A considerable number, and perhaps the majority, of surgeons believe that the operation should be postponed for a week to ten days, or even longer. The reasons given are: (1) that one should wait until all tendency to hemorrhage in the joint has ceased; (2) that one should wait until a reaction has occurred in the knee joint which will render it less liable to infection; and (3) that one should

wait until a small amount of callus is thrown out from the surface of the broken bone, as it is thought that this will tend to hasten union.

I do not believe that any of the above reasons is valid. We control the hemorrhage at the time of the operation, we do not create an artificial reaction in a clean knee before operating upon it, and in other fractures we do not wait for beginning callus before reducing the fragments. The only reasons for not operating immediately are shock to the patient, which prohibits any surgical procedure beyond those necessary for saving life, and damage to the skin over the patella, which makes it impossible to control asepsis. Ordinarily, with abrasions or lacerations of the skin, if the patient is seen within a few hours of the injury, it is possible by the use of strong antiseptics and by placing the incision away from the injured area to perform the operation without undue danger of infection. On the other hand, if the patient is seen twenty-four hours or more after the injury when the superficial abrasions or lacerations have become infected, then it is extremely unwise to operate until the skin wounds have healed, and even then the skin incision should be placed as far away as possible from the recently infected area. Consequently, if the condition of the skin and the general condition of the patient permit, I believe that the patella should be operated upon as soon after the injury as it is convenient to do so, preferably immediately.

Before the operation the extremity from the mid thigh to the middle of the leg is shaved, scrubbed with soap and water, washed with alcohol and ether, and painted with strong tincture of iodine or one of the newer skin antiseptics. A tourniquet is not used and the patient is placed on the operating table with a small sand bag under the affected knee.

The next question is—What anesthetic should be used? This depends entirely upon the choice of the surgeon and upon the condition of the patient. As the bone is superficial, local anesthesia can be used with entire satisfaction. I have employed in about half of the patients 1 per cent novocaine in the skin and ½ per cent in the deeper tissues. The novocaine solution contains three drops of adrenalin to the ounce, for this not only tends to control the hemorrhage, but tends also to counteract the toxic effect of the novocaine. The injection is made along the line of the proposed skin incision. The subcutaneous tissues under the skin incision are infiltrated with ½ per cent novocaine and about 10 c.c. of novocaine is injected well away on each side above the lateral margins of the skin incision opposite the tear in the aponeurosis. If preferred, a general anesthetic may be used.

A number of different types of incisions may be used. Most surgeons prefer either a vertical incision or a U-shaped incision which is convex downward. I prefer the U incision with a rather short flap, the bottom of the U being just below the distal end of the patella. With this incision the suture line in the skin does not lie over the fracture. The incision is carried down through the subcutaneous tissue to the lateral aponeurosis and the upper portion of the patellar ligament. The flap, including the subcutaneous tissues, is dissected upward and retracted after skin towels have been applied. This exposes the break in the bone and the tear in the aponeurosis, and through the break in the bone the knee joint is opened. The blood in the joint is evacuated and wiped out with gauze sponges. Any loose fragments of bone in the joint are removed. Likewise, loose fragments of bone which are completely detached or so nearly detached that their circulation is markedly impaired are removed.

If the fracture is a simple transverse one it will not be necessary to remove any loose fragments or to revise the edges of the fracture. However, if a comminuted fracture is present it may be advisable to remove a considerable portion of the bone and if this is done it may be necessary to revise the ends of the fragments which

remain in order to obtain as accurate a coaptation of the fracture line as possible. This can be done with rongeur forceps or bone cutting forceps. It will be found that the aponeurosis on either side of the patella is torn for a variable distance outward, the length of the tear varying directly with the degree of the separation of the fragments. This tear may be quite clean cut, but is usually rather irregular, with frayed margins. Likewise, the thin aponeurosis extending over the superficial surface of the bone is torn, usually in an irregular manner. Some fringes of fibrous tissue tend to hang down into the space between the fragments. These fringes are excised because it is not possible to suture them sufficiently firmly to be of value in holding the fragments together.

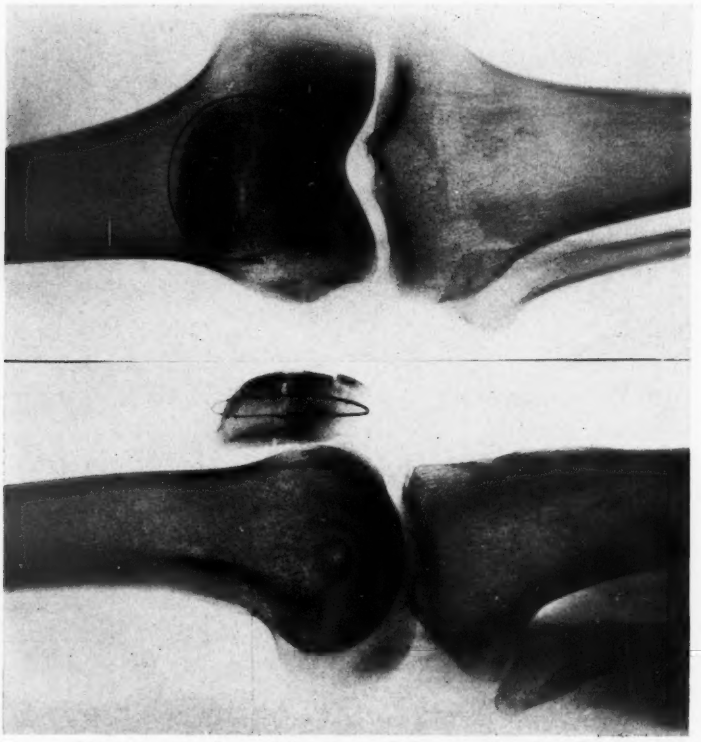


Fig. 2. Simple comminuted fracture of the patella after fixation by encircling stainless steel wire.

It is now necessary to coapt the fragments and hold them together until union has occurred or one may excise either all or part of the patella. There is a considerable difference of opinion as to how and with what materials the fragments should be held together. The various procedures advocated will be discussed below. We use stainless steel wire of the flexible type and of a strength sufficient to hold the fragment firmly together (20 or 22 gauge in a fresh fracture). This wire may be placed through or around the fragments or through the larger and around the smaller fragment, depending upon the size and shape of the fragments.

It will be noted that the distal fragment tends to be tilted in such a manner that the fractured surface tilts forward while the proximal fragment, which is usually the larger, is drawn directly upward. Consequently, in most instances a hole is drilled transversely through the larger (proximal) fragment and the wire is passed through it. The hole is made as close to the anterior surface of the patella as possible, because it is very important that the wire should not enter the knee joint, and also because it is important that it tend to pull the superficial or anterior margins of the fracture line together as this assures an

accurate coaptation of the articular surface. Then the wire is brought down through the lateral aponeurosis close to the and the lower up by sharp toothed retractors placed in the proximal and distal ends of each, respectively, so that the fractured

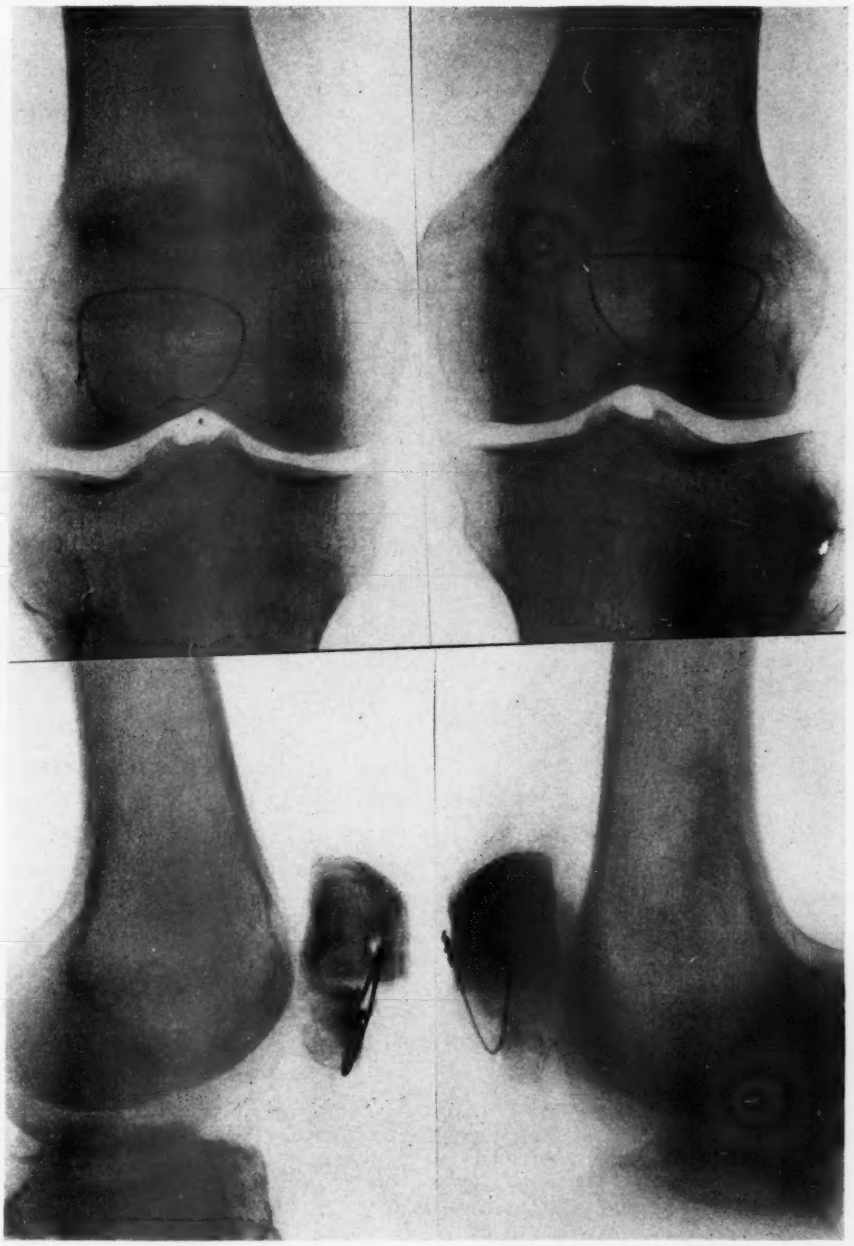


Fig. 3. A bilateral fracture of the patella wired with soft iron wire. No trouble with the wire after seven years. Both knees apparently normal.

margins of the patella, and passed either through another transverse drill hole in the distal fragment or, if this fragment is quite small and comminuted, through the patellar ligament just below this fragment.

The two fragments are then accurately approximated, the upper being pulled down surfaces are pressed together. Then the wire is pulled taut, twisted together and cut off. The twisted end is bent downward and inward and buried in the tissues alongside the lower pole of the patella. The lateral aponeurosis is now sutured with mattress sutures of D silk. It is to be noted

that the patella is first wired firmly together before the aponeurosis is sutured This is done for two reasons: (1) because after the patella is wired the aponeurosis can be sutured more easily and without undue tension; and (2) because the accurate apposition of the patellar fragments, which is important if one is to prevent postoperative arthritis of the knee, can be performed more readily before the aponeurosis is sutured. The mattress sutures take small bites in the aponeurosis on either side; usually about four such sutures are placed on each side of the patella. The subcutaneous tissues are then closed with fine silk and the skin is sutured with silk.

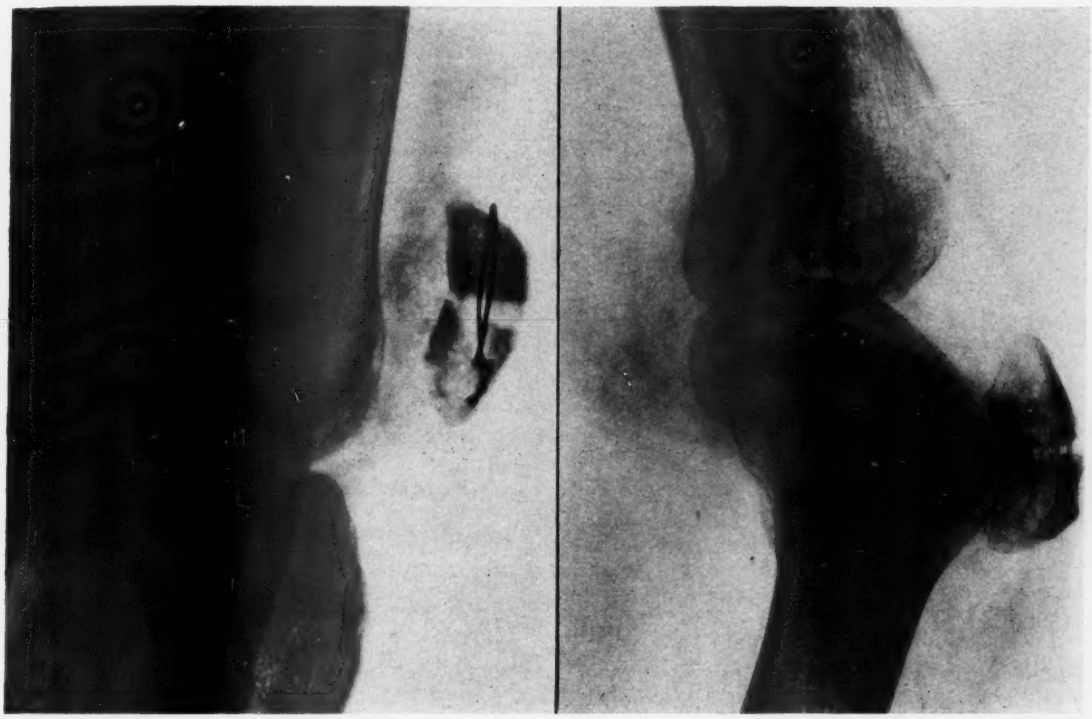
FIG. 4. Compound comminuted fracture of the patella debrided and wired after removal of about half of the bone. Uneventful recovery. Marked atrophy of lower fragment and questionable union in the *x*-ray.

Postoperatively the knee may be immobilized or not, depending upon the choice of the surgeon and upon the security with which the fragments of the patella have been fixed by the wire. The patient is more comfortable if it is immobilized in a cylinder plaster cast for about ten days, at the end of which time the cast is taken off, the sutures are removed and an elastic bandage is applied. The patient is encouraged to exercise the knee. If one prefers, however, and if the fragments have been securely wired together, no immobilization is necessary. An elastic bandage is applied over the dry dressing and the patient may begin to move the knee within three or four days after the operation. The sutures are removed at the usual time and the patient may be up on crutches at the end of two weeks. He is encouraged to exercise the knee, but is advised not to put his weight upon the extremity with the knee flexed. At the end of eight weeks union should be firm and almost normal motion in the knee should be present. The patient may begin light work within about four weeks, but should use a cane for at least eight weeks after the operation.

The stainless steel wire is used because the fragments can be fixed more firmly with wire than with any absorbable material or with silk. The stainless steel wire can be tolerated indefinitely by the tissues and has not, in my experience, caused trouble. There has not even been a great deal of difficulty with the wire in the two instances which I have seen in which postoperative infection of the wound occurred. The exact

manner of placing the wire depends upon the form and size of the fragments found at the operation. In some instances the wire is placed through both fragments, in some instances through one fragment and around the other, and in other instances around both fragments. (Figs. 2, 3, 4 and 5.) When one or both fragments are encircled with wire, this is placed through or just beneath the aponeurosis and care is taken that the wire does not lie in the joint cavity at any point. This is accomplished by threading the wire on a large curved needle, the point of which is brought out through the superficial fibers of the aponeurosis as often as is necessary to maintain the superficial position of the wire.

Before flexible stainless steel wire was obtainable I used soft iron wire (stove pipe wire) and found that even this type of wire is tolerated by the tissues over many years without difficulty. The bilateral fracture illustrated in Figures 4 and 5 was fixed with soft iron wire in 1932 and has caused no difficulty up to this time, the knees being to all intents and purposes normal. The patient is now over 60 years of age and leads a very active life.



A B

Fig. 5. A, simple fracture of the patella wired. Followed by postoperative infection. Wire left in until patella had united. B, same case after removal of the wire. Stable painless knee with about 70 degrees of movement six months after injury.

My objection to the use of fascia, chromic catgut, kangaroo tendon or silk for the fixation of bone fragments is that none of these can be relied upon to fix the fragments together as firmly as does wire. A further objection to the use of fascia is that it unnecessarily complicates the procedure. Likewise, I believe that there is more danger of postoperative infection after the use of fascia or heavy absorbable sutures, such as chromic catgut or kangaroo tendon, than there is after the use of a slender inert stainless steel wire. If wire were not available, I would choose heavy braided silk or linen and encircle both fragments, because there is a tendency for silk to be cut by the edge of the bone when it is passed through a drill hole and tied under tension. The objection which many men have to leaving non-absorbable material, such as wire or metal screws or plates, in bone will, I believe, disappear as the use of stainless

steel becomes more general. Other forms of fixation, such as screws or bone grafts are less effective and render the operation much more difficult. Obviously, anything that can be done to simplify the operation and the postoperative care should be encouraged. Especially to be condemned is the method of suturing only the lateral aponeurosis and not wiring or tying the bone fragments together. This procedure demands prolonged immobilization and invites nonunion. I believe that the importance of suturing the aponeurosis has been overemphasized. It is good surgery to suture the aponeurosis after the fragments have been wired together, but it is more important to coapt the bone fragments and hold them together until union has occurred.

Fig. 6. Old fracture of the patella. Lengthening of quadriceps and excision of ends of fragments necessary before wiring.

The question of excision of the lower fragment as advocated by Thomson[1] and Blodgett and Fairchild,[2] or of excision of the entire patella as advocated by Brooke,[3] Tippett,[4] and Blodgett and Fairchild[2] is one which may be given thought. Thomson excises the lesser of the two fragments, usually the lower, and fixes the patellar ligament or quadriceps tendon to the remaining fragment, thus eliminating the necessity of union by bone. He believes that this procedure shortens the convalescence and maintains a better function in the knee.

It is probable that in an instance such as that illustrated in Figure 4 it would have been wise to excise the lower fragment and suture the patellar ligament to the upper fragment with silk, because, while clinically there was union, the *x*-ray did not show union five months after the accident. The patient, being a compensation case, claimed that the fragments were not united. His doctors claimed that it would be necessary to remove the wire and the lower fragment, although there was no clinical indication for the removal of either and the knee was apparently normal with the exception of weakness from quadriceps atrophy. It is thus evident that the presence of wire in the tissues is slightly objectionable in compensation cases. However, I do not believe that this objection is of sufficient importance to bar its use when its other advantages are considered. This particular case was a severe compound comminuted fracture with fragments of a broken emery wheel in the tissues.

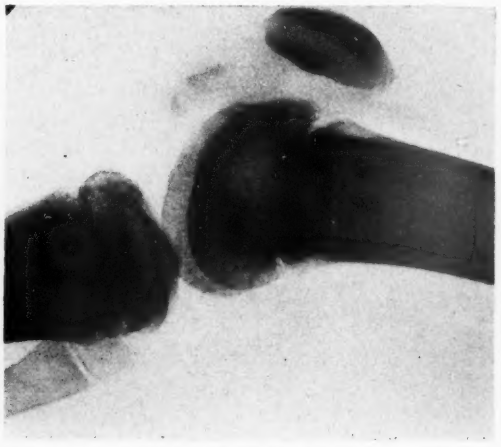


Fig. 7. Avulsion of patellar ligament sutured with heavy braided silk. Uneventful recovery.

Concerning the question of the removal of the entire patella, I have not performed this operation for fracture of the patella, although I have done it for ankylosis of the patella to the femur. However, the results and the experimental observations of Brooke[3] are very convincing and I see no reason why it should not be done, espe-

cially in severely comminuted fractures with separation of the fragments. On the other hand, it is quite a radical procedure and I do not believe that it will be generally adopted as a treatment for uncomplicated fractures of the patella.

COMPOUND FRACTURES OF THE PATELLA

A compound fracture of the patella is similar to a compound fracture of any other bone plus an opening into the knee joint and if it is seen early (within six to ten hours after the accident) it should be thoroughly debrided and sutured. The debridement is carried out according to standard principles, excising the skin edges, removing all foreign matter and loose fragments of bone and then washing out the wound and washing out the knee joint with a large amount of warm normal salt solution. Any devitalized tissue is excised. The fragments of the patella are then fixed with stainless steel wire just as described above for a simple fracture and the aponeurosis is sutured, either with silk or chromic catgut, according to the preference of the surgeon. The skin and subcutaneous tissues are sutured in one layer with interrupted silkworm gut sutures and a small rubber drain is inserted on either side. This drain may be placed down to the capsule or may extend into the knee joint, depending upon whether one believes that he has performed an adequate debridement sufficiently soon after the injury to be reasonably sure that the knee will not become infected. This drain is removed at the end of forty-eight hours and the fracture is treated as a simple fracture. (Fig. 4.) After suture of the patella for a compound fracture the knee is immobilized in a well-padded plaster cast which extends from the toes to the groin and vaseline gauze is placed over the suture line to permit drainage, the skin being sutured rather loosely. The knee is immobilized in a cast because I believe that this is an important factor in the prevention of infection. Sulfanilamide in doses of 15 gr. every four hours should also be given as a prophylactic against infection in severe compound fractures.

If there should be evidence of infection, as indicated by a rise in temperature, a rise in the pulse or an unusual amount of pain in the wound, the cast should be bivalved and the wound inspected immediately. Sufficient skin sutures should be removed to determine whether or not the infection is in the superficial tissues or in the knee joint. If the infection is deep, the joint should be opened freely and a large wet dressing applied, at the same time maintaining immobilization. I have not found that the presence of the wire was a detrimental factor in the early days of an infected wound and believe that its immobilizing effect is a distinct benefit. In such wounds, however, it is usual to remove the wire after the infection has quieted down, but before it has healed.

In very severe fulminating infections it is advisable to remove the wire, separate the fragments, remove all loose fragments and, if necessary, remove the patella. However, this has not yet been necessary in my experience.

If the infection is found to be due to a streptococcus or to a gas bacillus a massive dose of sulfanilamide (90 gr.) should be given immediately and should be followed by 15 gr. every four hours. This is continued until the patient's temperature has dropped to a satisfactory level and the infection has subsided, or until it is necessary to stop the drug because of an idiosyncrasy. In addition to the chemotherapy the wound should be treated surgically as described above.

Throughout the process of the treatment of the knee for an infection due to a compound fracture of the patella or due to a postoperative infection of a patella which has been sutured, the knee should be kept in a straight position and no attempt should be made to move it until the infection has subsided and the deeper tissues have healed. Usually it will be found that this will result in a localization of the infection in the front of the knee joint. After the

infection has subsided and the wounds have healed there will be a slow, but progressive return of function and in most instances the range of movement will increase over a period of months (Fig. 5), although occasionally bony ankylosis at the knee may occur.

OLD FRACTURES OF THE PATELLA

In old fractures of the patella the fragments are usually widely separated and the proximal fragment is maintained in its abnormal position by contracture of the quadriceps muscle. In addition to the above, the ends of the fragments are sealed over by scar tissue. Likewise, there is a thin layer of scar tissue bridging the space left by the tear in the lateral aponeurosis on either side of the patella. In treating such a lesion it is necessary to excise the scar tissue between the torn ends of the aponeurosis and to excise the ends of each fragment in order that fresh bleeding bone may be exposed and opposed. After this has been done it will usually be found that it is not possible to pull the two fragments together. Not only is the proximal fragment displaced and held up on the thigh, but the distal fragment is displaced downward.

In order to coapt the two freshened bone surfaces it will usually be necessary to lengthen the quadriceps tendon. This can be done by the z method or by the tendon plastic method of Bennett in which a long tongue of the quadriceps tendon is cut free and slipped downward and then sutured at a lower level by suturing the muscle fibers to it on either side. However, in performing this operation it is to be noted that lengthening of the central tendon itself will not permit downward displacement of the patella, nor will it permit flexion in a knee which has become fixed in extension by contractures. The real fixation of the patella upward on the femur is not due to the quadriceps tendon, but is due to the shortening of the tissues on either side of the upper pole of the patella which bind it to the femur just above the condyles. These are largely portions of the vastus internus and externus, and these fibers must be cut across, opening the quadriceps bursa of the knee joint and freeing the upper pole of the patella on either side. Then the upper fragment can be pulled downward, swinging by a pedicle of tissue on either side and carrying with it the freed quadriceps tendon above. This will leave a dead space or gap 1 to 2 inches wide in the quadriceps muscle on either side at the upper pole of the patella. I have usually left the space open, but occasionally I have partly obliterated it by transplantation of muscle fibers. It apparently takes care of itself and has not caused any trouble, except worry, until the danger of infection is over.

After the quadriceps apparatus has been lengthened to such a degree that the upper fragment can be brought downward, the two fragments are held together with sharp toothed retractors and are fixed with a wire loop, just as though one were dealing with a fresh simple fracture. Then the aponeurosis on either side is sutured with silk and the wound is closed in the usual manner. For this operation a long anterior incision is used, the incision curving inward around the mesial aspect of the patella, extending down to the tibial tubercle and as far upward on the thigh as is necessary. After the operation it is advisable to immobilize the extremity in a plaster of Paris cast with as much flexion as can be obtained without undue tension on the fragments. The immobilization is continued for from two to four weeks, depending upon the postoperative course. (Fig. 6.)

TREATMENT OF AVULSION OF THE QUADRICEPS TENDON OR OF THE PATELLAR LIGAMENT

In these instances the tear is usually close to the upper or lower pole of the patella and not infrequently a small amount of bone is torn off with the tendon. It is not practicable to fix the tendon to the bone with wire because the wire pulls through the vertical tendon fibers and becomes loose and when the wire becomes loose it acts as an irritant. Consequently,

for these injuries I use heavy braided silk sutures, weaving the silk into the tendon and leaving four strands of silk projecting from the torn end of the tendon. Then two drill holes are made in the patella, passing vertically upward or downward through the bone, keeping well away from the articular surface. The heavy silk is passed through these drill holes and tied firmly at the opposite pole of the bone. The torn aponeurosis is sutured with silk in the usual manner and the subcutaneous tissues and skin are closed with silk.

Postoperatively the knee is immobilized in a plaster of Paris cast for four weeks. It is not felt that the silk is strong enough to permit free use of the knee before this time, nor is it felt that the union between the torn tendon and the bone will be sufficiently strong to permit freedom of the knee without danger that the sutures may be torn loose. At the end of this time the cast is removed and the patient is encouraged to begin exercising the knee and to bear weight upon it with the knee in the straight position. He may walk with crutches or with a cane, but is cautioned against putting his weight on the flexed knee. A very strong and useful knee may be expected within eight to twelve weeks and a practically normal knee within about six months. (Fig. 7.)

SUMMARY

Simple fractures of the patella without separation of the fragments are treated by immobilization in a plaster of Paris cast. If the fragments are separated they are reduced by open operation and tied together. A loop of stainless steel wire is preferred to any other type of suture. The tear in the lateral aponeurosis is sutured with D silk. Avulsions of the quadriceps tendon or of the patellar ligament are repaired by heavy silk which is passed through two drill holes in the patella and tied at the opposite pole of the bone. The management of compound fractures, of infected fractures and of old fractures of the patella is described.

REFERENCES

1. Thomson, J. E. M. Comminuted fractures of the patella. *J. Bone & Joint Surg.*, 17: 431, 1935.
2. Blodgett, W. E., and Fairchild, R. D. Fractures of the patella. *J. A. M. A.*, 106: 2121, 1936.
3. Brooke, R. Treatment of fractured patella by excision. A study of morphology and function. *Brit. J. Surg.*, 24: 733, 1936–1937.
4. Tippett, G. O. Treatment of fractures of the patella by excision. *Brit. M. J.*, 1: 383 (Feb. 19) 1938.

FRACTURES OF THE KNEE

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PRACTICALLY every fracture is an individual problem. For this reason it is difficult to standardize methods of treatment. Each fracture of the knee is considered a unique problem to be treated by that method offering the best result. The requirements for obtaining such a result are:

1. *Smoothness of the Joint Surfaces.* This is a requirement of great importance. Roughened weight-bearing joint surfaces are most likely to become permanently painful and disabling. Anatomic position, though not so essential in the shaft of a bone, is important in fractures within the joint. Accurate replacement of fragments to obtain smooth joint surfaces is essential for good function.

2. *Length.* Should be equal to that of the opposite leg.

3. *Good alignment* to restore as nearly as possible normal mechanics of the lower extremity so as to have neither a knock-knee nor a bow leg.

(The good knee serves as a guide for the proper angle between the tibia and the femur.)

4. *Good apposition* must be better than one might be willing to accept in the muscular area of an extremity. At the knee the bone is entirely superficial, and a defect unnoticed in the mid shaft of a bone would be conspicuous in the head of the tibia or in either condyle.

There are certain obligations due the patient from the beginning of treatment. His pain should be relieved as quickly as possible. Immediate splinting in whatever position is most comfortable, plus a narcotic, may be all that is necessary. If not, the fracture can be infiltrated with 10 to 20 c.c. of 2 per cent novocaine before the patient is transferred to the hospital, provided of course that the skin is in good condition. Careful handling of the leg is not only gratifying to the injured person, but will sometimes prevent a sharp edge of bone from piercing the skin and making a compound wound.

Upon arrival at the hospital the patient is immediately taken to the operating room where he is transferred to a wheel carriage. *X*-rays are made there with a portable apparatus to minimize movement of the leg. The *x*-rays are studied and plans are made for reduction of the fracture. If it appears that manipulation or skeletal traction and plaster cast fixation would accomplish a permanent and satisfactory reduction, preparations are made while the patient is given a general examination, including urinalysis and blood studies. A general anesthesia is given the patient while he is still on the wheel carriage and he is then placed on the fracture table. If good position of the bones is not obtained, an open reduction and internal fixation with rustless steel wire, bands, screws or nails may be done immediately if the patient's general condition will permit. This can usually be done subperiosteally or without extending the incision into the knee joint.

Should there be a compound wound, it is cleansed, and closed or drained depending upon the number of hours that have passed since the time of injury. Gas bacillus and antitetanic serum are given. If there be shock or complicating injuries, plaster splints (posterior, lateral and medial) are applied from the toes to the groin and the fracture may be treated any time within the following ten days. When there is a marked displacement of the bones into the popliteal space, pressure on the blood vessels and nerves must be immediately relieved. It is important to know the condition of the circulation and of the nerves to the leg and foot in every fracture

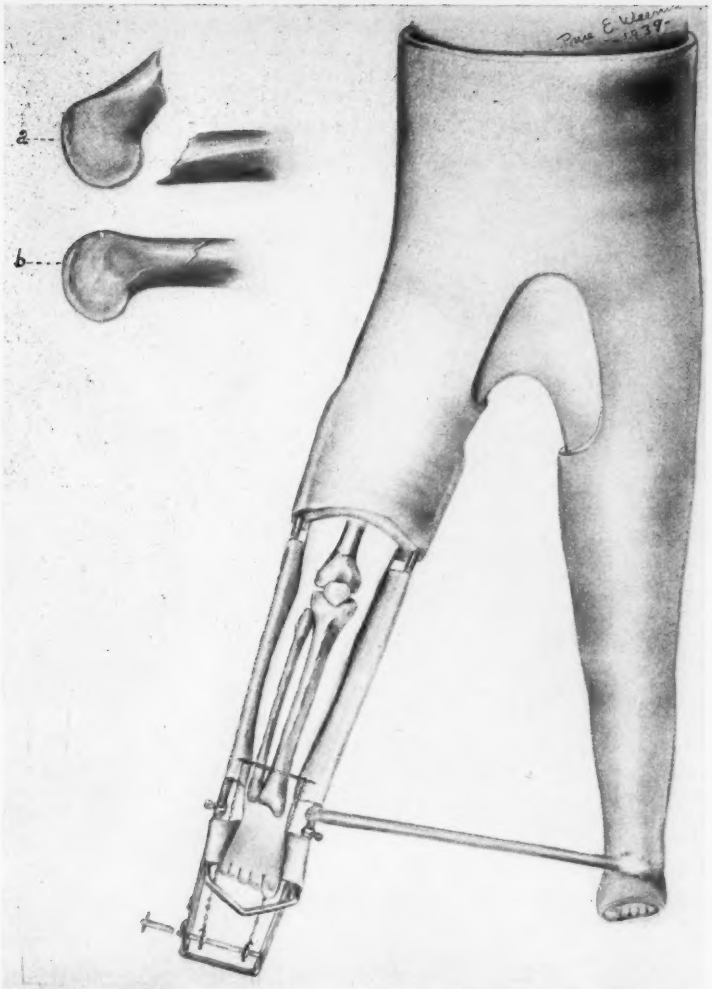

FIG. 1. Supracondylar fracture of femur reduced by skeletal plaster traction. "The principle of this apparatus is that while traction is applied to the fractured extremity, countertraction is being applied to the sole of the opposite foot." It is applied as follows:

"A suit of stockinet is put on. Felt padding should line the back and sides of the body and pelvic portion of the cast. A double spica cast is applied, extending from mid-abdomen to the toes of the unaffected leg and down the injured leg to a point above the fracture. The unaffected leg is held in a position parallel with the midline of the body to facilitate turning the patient from back to side and abdomen. The foot of the unaffected side is held in a normal weight-bearing position, i.e., with the sole of the foot at right angle to the leg. This foot should be well padded with sheet wadding. Felt has been found unsatisfactory for this purpose."

General anesthesia is then given and a Steinmann pin is inserted with an electric drill through the lower end of the tibia. A traction ratchet is attached to the cast as shown; the Steinmann pin is connected with the ratchet with small size brass chain. Traction is obtained by winding the chain on the ratchet.

Precautions: "The cast should be well padded, especially over the lateral surface of the hip and pelvis of the injured side, as considerable pressure is exerted on this surface when traction is applied. The upper end of the inner bar of the traction splint should not be closer than a hand's breadth to the perineum. The reason for this precaution is that as the injured extremity is pulled downward by the traction, the perineum might come in contact with the upper end of the bar and cause serious pressure. For the same reason, the cast should be trimmed at least a hand's breadth below the perineum."*

Note: A valuable method also in treating fractures of the shaft of femur in children. In small children adhesive tape on the leg is substituted for the Steinmann pin.

* THORNTON, LAWSON. *Piedmont Hosp. Bull.*, May and June, 1925.

of the knee. Pressure on the peroneal nerve by a spicule of bone from the head or neck of the fibula is another complication requiring immediate correction, possibly by open reduction. In one instance where the knee had been violently twisted in an automobile accident, the circulation was so inadequate as to necessitate an amputation on the tenth day. The popliteal artery was found to be torn and thrombosed.

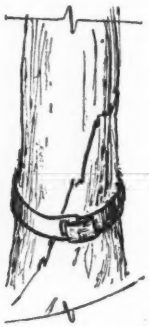

Fig. 2. Oblique supracondylar fracture of the femur may be satisfactorily held with a Parham band placed subperiosteally around the bones through a small incision on each side of the knee.

Fig. 3. Fracture of the patella. *X*-ray before operation.

Fig. 4. Fracture of patella. *X*-ray after open reduction held with a circular rustless steel wire.

The accompanying drawings and *x*-rays illustrate some of the types of fractures and methods of treatment. Plaster cast fixation is used in all cases because it provides the best chance for maintaining the reduction and a maximum of comfort and immobilization. The patient is given freedom of the bed, wheel carriage or wheel chair. Steinmann pins are preferable to Kirschner wire because the unnecessary bulk and weight of the Kirschner clamps are eliminated.

After reduction the leg is carefully watched for swelling and the cast is split and spread whenever necessary. The knee is always held in extension with possibly 5 or 10 degrees of flexion; the foot is always held in midposition and at a right angle to the leg. When the *x*-ray shows that there is sufficient union (eight to ten weeks) the cast is removed and passive and active motion of the knee is begun. During the first few days the patient is kept in bed for continuous application of heat. Then he is allowed to walk on crutches, with or with-

out a brace, depending on the type of fracture or the degree of union. Each day for the following month or more the patient is under the care and direction of an expert physiotherapist. He is given baking, massage, active and passive knee motion, exercises and development of the muscles with the Morton Smart galvanic current machine. Such continuous and persistent treatment is valuable and not only shortens the period of disability but is an excellent means of approximating normal knee function.

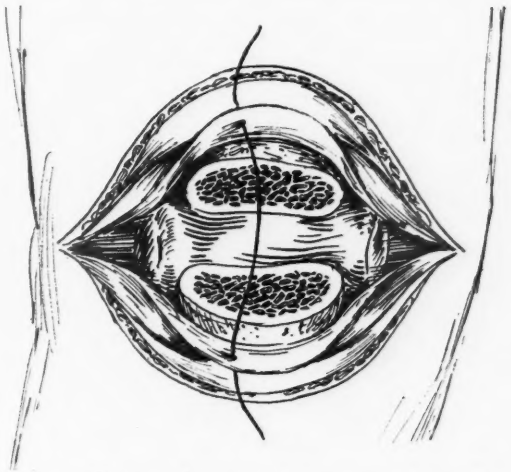

Fig. 5. Open reduction of fracture of patella. Separated patella exposed. The first interrupted chromic catgut suture in capsule and anterior fascia has been placed.

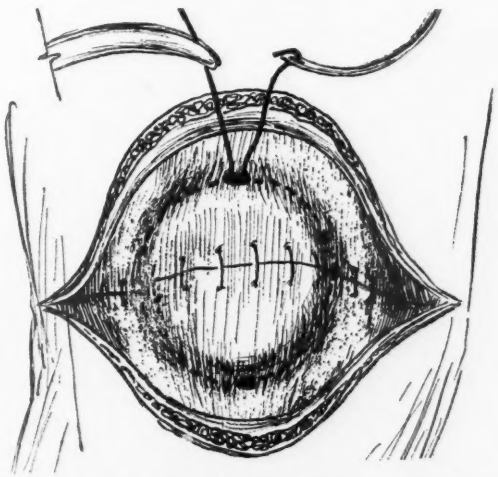

Fig. 6. Operation for fracture of the patella completed. The fracture has been reduced and held with a rustless steel wire encircling the periphery of the bone (dotted). The two ends of the wire are shown just before twisting and cutting the knot short. The capsule and fascia have been closed with interrupted chromic catgut sutures.

It is usually true that in fractures of the knee neither the lateral nor the crucial ligaments are ruptured. The reason probably is that the bone "gives way" before the ligaments can be torn. Even with a tearing of one of these ligaments, satisfactory healing may occur during the weeks

A

B

FIG. 7. *X*-ray of split fracture of the head of the tibia before and after reduction by method shown in Figure 8. (From Thornton, in "Cyclopedia of Medicine," F. A. Davis Co., Vol. v, 1932.)

of immobilization in a plaster cast, resulting in a stable joint. In one of the accompanying illustrated cases there was a complete rupture of the patellar tendon that was not discovered until incision was made for open reduction of the comminuted fracture of the head of the tibia.

Should the knee joint be unstable as result of ligament relaxation following healing and after the muscles have been improved by physiotherapy, surgical repair of lateral or crucial ligaments may be necessary.

CASE REPORTS

Fracture of Patella with Wide Separation. Mr. S., age 44 years. (Figs. 3–6.) June 12, 1932, the right patella was fractured in an automobile accident. The patella struck the instrument board when patient was thrown forward by the sudden stopping of the car.

Operation was done June 13. A transverse incision throughout the anterior half of circumference of the knee exposed a badly torn capsule and the shattered patella. The torn synovial membrane was closed with fine catgut. Four deep chromic catgut stutures were taken on each side of patella to approximate the torn capsule and fascia. A removable rustless wire was threaded around the fragments of the patella, as shown in the *x*-ray. Fine plain catgut was used to approximate the superficial layers of fascia and fat. The leg was immobilized in a plaster cast extending from toes to upper thigh.

On July 11, 1932, the cast was removed and physiotherapy and walking with crutches were begun.

Result: July 27, 1932 the patient was dismissed with normal function.

Fracture of Head of Tibia. Mr. M. J., age 49 years. (Figs. 7 and 8.) On September 22, 1930, the bumper of automobile struck his leg below the knee. *X*-ray (Fig. 7) showed displacement of fragments involving the knee joint. The fracture was treated in the following manner:

Reduction: "Under general anesthesia, a Steinmann pin (Fig. 8*a*) was placed through the femur just above the condyles, and another Steinmann pin (*a'*) through the heel. A plaster cast (*b*) was applied, extending from the groin

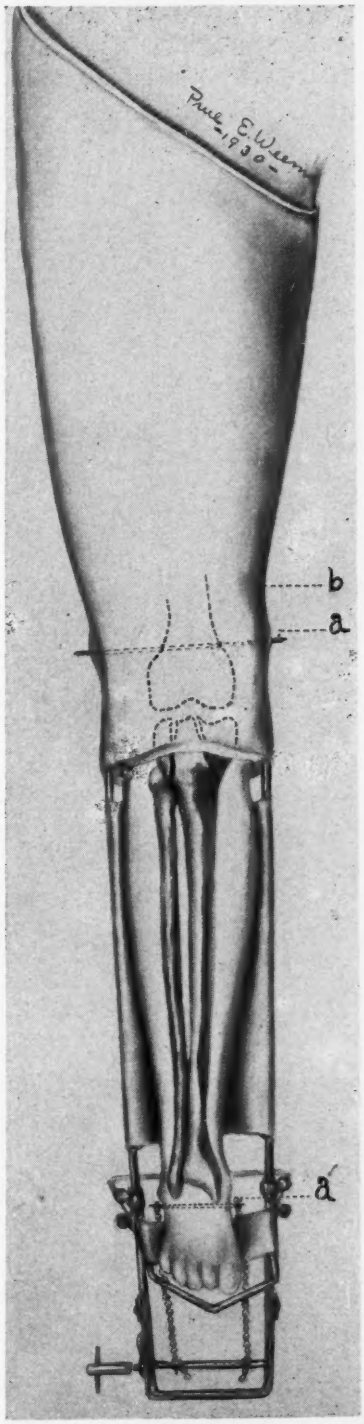

Fig. 8. Drawing illustrating method of reduction of split fracture of head of tibia. The same principle of fixed skeletal traction shown in Figure 1 is used. The Steinmann pin through lower femur (*a*) is used here in place of countertraction on the sole of the opposite foot as in Figure 1. (From Thornton, in "Cyclopedia of Medicine," F. A. Davis Co., Vol. v, 1932.)

to a point above the ankle. The ends of the Steinmann pin, through the femur, were incorporated in the cast. A ratchet traction apparatus was attached to the lower end of the cast by means of plaster bandages. Two small brass chains connected the heel pin with the ratchet windlass. When the windlass was wound, traction was applied through the heel pin, and countertraction by the pin through the femur. After four weeks in this traction apparatus, the cast and pins were removed and a new plaster cast applied, extending from upper thigh to the toes, to be worn for two more weeks. It was then removed and motion and physiotherapy were begun."

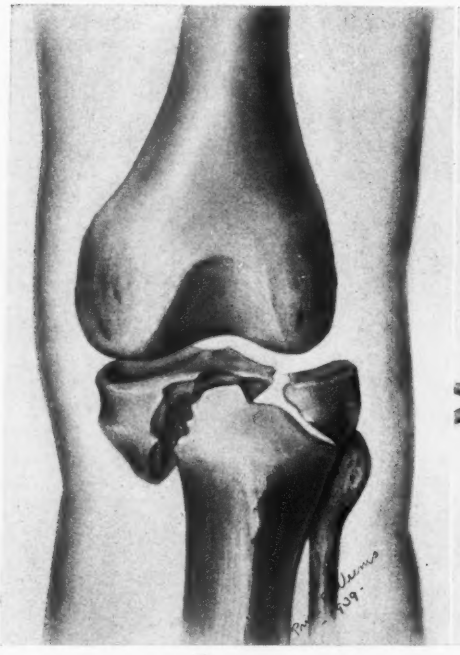

FIG. 9.

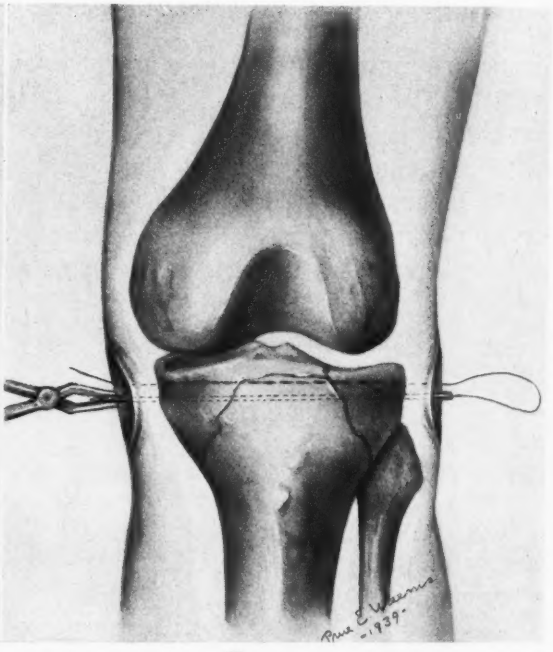

FIG. 10.

FIG. 9. Drawing from the *x*-ray of a comminuted fracture of the head of the tibia.

FIG. 10. *X*-ray of tibia shown in Figure 9 after reduction by the following method: The fracture was reduced with traction and manipulation. The bones were held in place with a through and through rustless steel wire suture passed through holes in the bone made with a drill as shown. The posterior end of the drill is hollow and serves as a wire carrier. A small incision is made on each side of the tibia near the knee joint articulation. The drill as shown is making the return passage close to the point of original entrance.

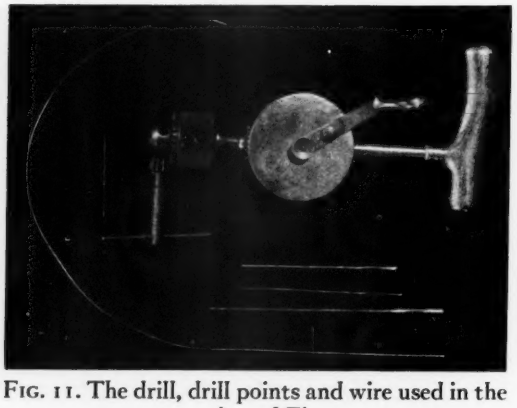

FIG. 11. The drill, drill points and wire used in the operation of Fig. 10.

On October 17, 1930, the cast and Steinmann pin were removed. The pin wounds were clean. A new cast was applied. This was removed November 15, and physiotherapy, heat, massage, and motion were given.

On November 24, 1930, the patient was dismissed, walking with crutches and possessing 60 degrees motion. In June, 1932, he had 95 degrees knee motion, no lameness. He was comfortable and had no deformity.

Fracture of Head of Tibia. Mr. W. M. C., age 21 years. (Figs. 9, 10 and 11.) On May 1, 1932, three days after injury by a farm tractor, open reduction was done. Fragments were replaced by tightening strong, rustless steel wire threaded through channels drilled through the fragments. Plaster cast immobilization was necessary for six weeks. Normal range of motion of the knee, with normal function and no pain, resulted.

Comminuted Fracture of Head of Tibia with Rupture of Patellar Tendon. Mrs. F. Y., age, 35 years. (Figs. 12 and 13.) On November 3, 1938 the head of the tibia was fractured into knee joint when the patient hit her leg below the knee against a log while hiking. *X*-ray showed considerable displacement and roughening of the floor of the joint. Traction and manipulation under general anesthesia did not give a satisfactory reduction.

Fig. 12. *X*-ray of comminuted fracture of head of tibia.

Fig. 13. *X*-ray of tibia shown in Figure 12 following open reduction and fixation with two wire sutures.

Operation was done November 11, 1938. Through a midline vertical incision, close to the tibial tubercle and without exposure of the joint, the bones were levered into good position and held with two circular rustless steel wires. *The patellar tendon was found to be completely ruptured* and was sutured with chromic catgut. A plaster cast was applied from toes to groin. The leg was immobilized for seven and one-half weeks. Patient then had one week in bed for joint motion with daily physiotherapy, followed by walking with crutches, physiotherapy being continued.

On February 13, 1939, she walked without support, and had 75 degrees of comfortable knee motion. The maximum degree of motion has not yet been obtained. Continued improvement is expected.

Fracture of Patella (Old) with Contracted Quadriceps Tendon. Mr. C. B., age 20 years. (Figs. 14 and 15.) The left patella was fractured on July 10, 1938 in an automobile accident. The patient was unable to extend leg. *X*-ray showed fracture with about a 2 inch separation of the fragments.

At operation, on November 21, 1938, the space between the separated fragments was filled with dense scar tissue. After this was excised and the upper fragment with its

quadriceps tendon freed of adhesions, approximation of the fracture was still impossible on account of the contracted quadriceps tendon.

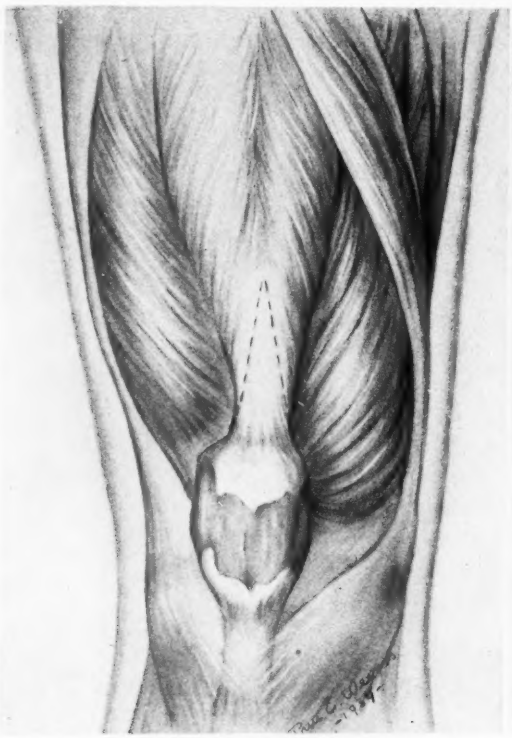

Fig. 14. Drawing of condition found at operation of fractured patella four months after injury. Operative correction in Figure 15.

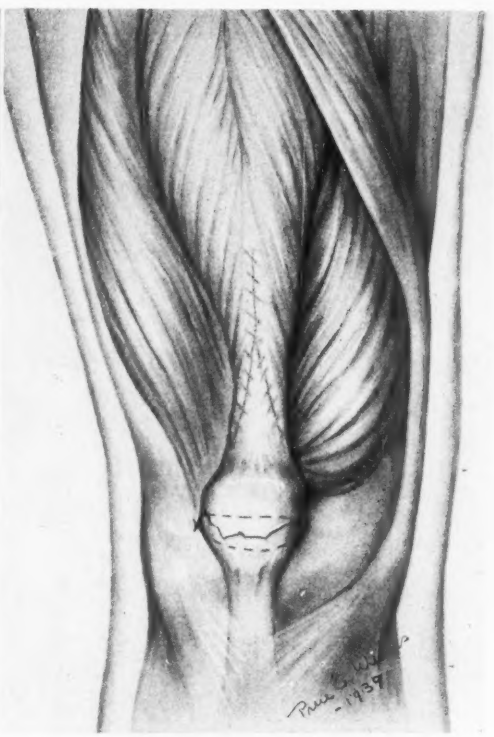

Fig. 15. Drawing of completed operation for condition shown in Figure 14. It was necessary to lengthen the quadriceps tendon for approximation of the separated patella fracture.

Fig. 16. Detail of moulding a leg plaster cast about the tibial tubercle to prevent rotation.

The tendon was lengthened and resutured and the patella wired together with a circular rustless steel wire. Plaster cast, knee extended, was worn for five weeks. The patient was instructed in development of knee motion.

On February 15, 1939, he was walking well and comfortably. The knee could be bent to 90 degrees and was possessed of good power of extension.

EXTRA-ARTICULAR FUSION OF THE HIP JOINT FOR TUBERCULOSIS

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TUBERCULOSIS of the hip is most unfavorable to the occurrence of intra-articular arthrodesis, or fusion, either as a spontaneous event, or by operative measures. The reasons for this are obvious: (1) inhibition of osteogenesis by the tubercle bacillus; and (2) the anatomical contours of the joint cause recession of bone surfaces from each other as bone destruction progresses, or following intra-articular removal of bone by the surgeon for arthrodesis purposes. The ball and socket contour of this joint causes the femoral head to be smaller and the acetabulum to become larger from pathologic erosion or surgical removal of the joint surfaces. Again, because of the anatomy and mechanical relationships of the hip and pelvis, as extensive destruction progresses, the diseased bony surfaces of the femur and pelvis are prevented from approximating because of impingement of the inside of the great trochanter against soft parts at and above the rim of the acetabulum. Since the tubercle bacilli inhibit active osteogenesis which would normally take place, dead spaces are left between the bony elements, and spontaneous ankylosis and cure become improbable.

Bracing in cases of extensive destruction with spaces filled with caseation has, for the same reason, been signally unsuccessful. This inhibition to healing has been so striking that many cases have been seen where complete destruction of the head and neck of the femur has occurred, so that *x*-ray studies show a mere spike remnant of the head and neck displaced into the acetabulum which has become markedly enlarged to over double its normal size. This enormous cavity is filled with caseous material with no possible chance of spontaneous fusion even after ten years or more of conservative treatment. Such cases are associated with 3 to 4 inches of shortening and a limb including the foot that is one-half to two-thirds the volume of the other. The knee is markedly "knock-kneed" with laxity or almost complete destruction of the lateral ligaments from the constant lateral pressure of braces or splints over so many years. (Figs. 1, 2 and 3.)

The contrasting result when extra-articular arthrodesis has been done early is great. A normal knee, with good function, is present, and the limb is only slightly atrophied, with little shortening. The success of operative treatment has been so spectacular when compared with prolonged conservative treatment that it is not strange that the pendulum has swung so strongly toward early operation in tuberculosis of the hip, as well as of the spine and certain other joints.

Extra-articular arthrodesis, first used by the author in 1913, and described in 1919, has proved most satisfactory. By strongly bridging the joint with a tibial, femoral or iliac graft or grafts mortised into the bony elements on both sides of the joint, complete fixation is secured. The immobilizing influence of extra-articular union of the femur to the pelvis makes it unnecessary to enter the infected area. (Fig. 4.)

This operation has now been employed by the author for twenty-six years with very satisfactory clinical and functional results.

In the *Annals of Surgery* (March, 1929) he reported in detail the results obtained in thirty-one cases, and in the past ten years, forty-seven equally successful cases have been accumulated.

X-rays taken a few months after operation show the grafts firmly in place, and those taken several years later (even twenty-six years after operation) reveal marked proliferation of the grafts, and illustrate well the strong bridging support which this type of extra-articular arthrodesis affords. (Fig. 5.)

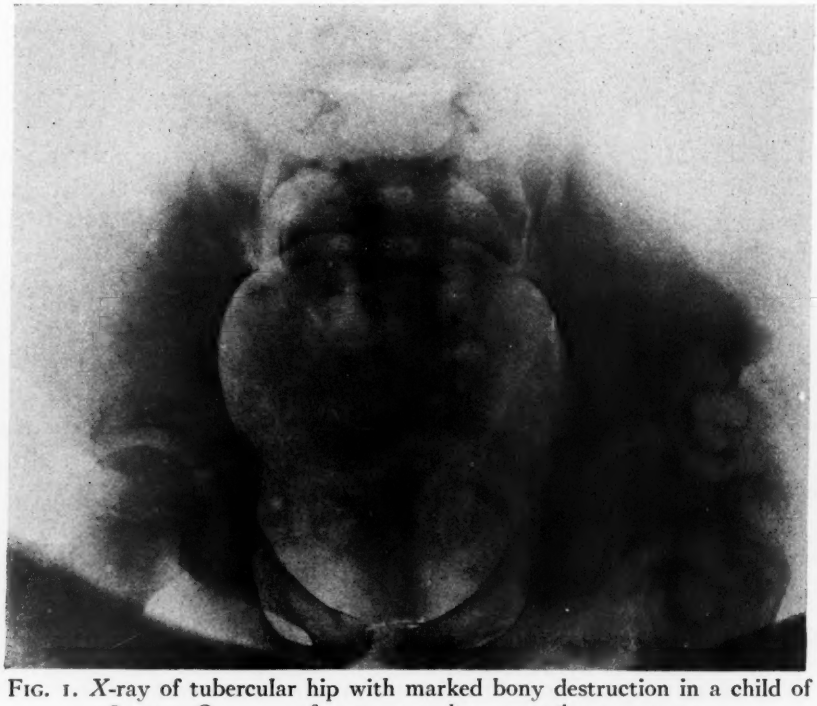

Fig. 1. *X*-ray of tubercular hip with marked bony destruction in a child of 8 years. One year after onset and conservative treatment.

FOUR VARIATIONS OF TECHNIQUE ADAPTED TO VARYING DEGREES OF DESTRUCTION

From his experience with extra-articular arthrodesis of the hip during the past twenty-six years, the author has been convinced more and more that it is distinctly advantageous to the surgeon to have more than one type of operation to select from in meeting the variety of mechanical requirements. Extra-articular arthrodesis in active tuberculosis is best brought about between the great trochanter on one side of the joint and the side of the ilium just above the rim of the pelvis on the other, and since the proximity of the trochanter to the side of the pelvis and the rim of the acetabulum varies widely in accordance with the degree of telescoping of head and neck into the pelvis from joint destruction or adduction and flexion deformity, the operative technique must vary accordingly. As in every surgical procedure, the simplest technique associated with the minimum of trauma and shock to the patient should be chosen, as well as the one which will interfere the least with a future arthroplasty, should it be desired and prove feasible.

From the technical standpoint, cases suitable for extra-articular arthrodesis of the hip can be divided into two groups, on the basis of pathologic and *x*-ray findings.

Group 1. In the first group, the destruction is moderate in amount without telescoping and the great trochanter remains widely separated from the side of the pelvis, so that a bone graft cannot be obtained from the side of the ilium or the immediate locality in sufficient length and strength to serve as a bridge for the extra-articular arthrodesis. The surgeon is compelled to go to the tibia or the outer portion of the upper end of the femur for graft material.

The patient is anesthetized to muscular relaxation and placed upon the fracture-orthopedic table. The surgeon forcibly corrects the adduction of the diseased hip by manual counter-pressure, placing one hand against the buttock and the other against the inner aspect of the knee. His assistant at the same time, by adjusting the fracture-orthopedic table, places the well leg in the limits of physiologic abduction and cautiously swings into a position of abduction —the traction arm of the table holding the diseased leg. The amount of abduction in which the latter is placed depends upon the amount of bony shortening. The practical shortening of the operated leg should never be less than ½ inch. Locomotion is better when there is a little apparent shortening in the limb of the ankylosed hip. When the shortening is so great that it cannot be made up in a practical way by fusion of the hip at an obtuse angle with the pelvis, the surgeon must use his judgment as to the degree of abduction desired in the particular case. This method of correction, partly by mechanics of the table, and partly by manual pressure over the lower end of the femur, is adopted in order to guard against overstretching the lateral ligaments of the knee joint.

Fig. 2a. *X*-ray after many years of conservative treatment, showing marked bone destruction.

Fig. 2b. Schema of Figure 2a. Arrow a indicates a small spike of bone, all that remains of both head and neck of femur.

A somewhat curved incision starting at the crest of the ilium, 2 inches posterior to the anteroposterior spine and carried down below the great trochanter, is made through the skin. The gluteal muscles are separated sufficiently to expose the side of the ilium at the points of mortise for the insertion of the proposed tibial grafts.

Because of the thinness and elasticity of the bone comprising the outer table of the ilium, a mortise suitable to receive the grafts can be satisfactorily made with an half-inch chisel driven through the outer table of the ilium obliquely upward between it and the inner iliac table, with the handle of the chisel in close proximity to the trochanter. With the cutting end of the chisel still in the mortise prepared by it, located 1 inch posterior to the antero-superior spine, and 1 inch below the crest of the ilium, the handle is depressed onto the outer surface of the trochanter at its anterior border, and used as a guide for some cutting tool, such as the scalpel, to mark on the periosseous structures the line

where the motor saw is later to prepare a trochanteric gutter for graft No. 1.

The same preparation is made for graft No. 2, except that the mortise in the ilium is made about 1½ to 2 inches posteriorly to the first one, and the scalpel mark is made on the posterior outer surface of the great trochanter. These cuts beside chisel No. 1 and 2 are in the relation of rafters to a ridge pole.

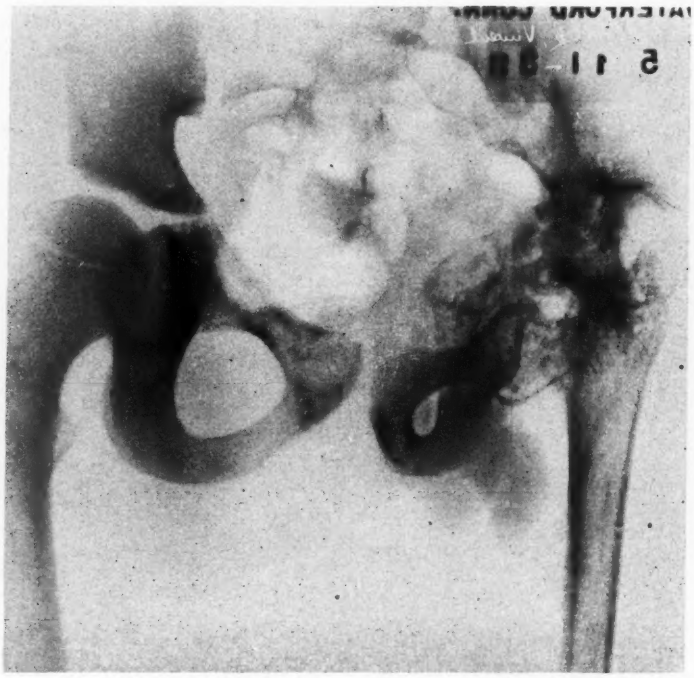

Fig. 3. *X*-ray of tubercular hip in boy of 12 years after six years of immobilization in a plaster of Paris spica and recumbency in bed. In spite of this constant treatment, there has been so much bone destruction that the pelvis on the involved side has been bisected and marked disintegration of the femoral head and neck and of the acetabulum has taken place.

Saw cuts are now made ½ inch in depth with the motor saw, following the scalpel marks just made on the trochanter. With an osteotome driven into these saw cuts, fragments of the trochanter are displaced with the periosseous soft parts as hinges, anteriorly from the saw cut for graft No. 1 and posteriorly from the saw cut for graft No. 2, so as to produce gutters to receive the two grafts with pedicled bone fragments to pull over them.

The antero-internal surface of the tibia is then laid bare from the tubercle of the tibia downward. With the motor twin-saw set with the blades approximately ⅝ inch apart, a graft is removed by saw cuts made downward from the tubercle of the tibia about nine inches. With a motor saw, this strip of bone is then cut into two segments. The upper ends of the grafts are cut in an oblique way like the end of a chisel.

The upper end of graft No. 1 is inserted into the mortise of the ilium with its lower end lying in the anterior gutter prepared in the trochanter. The oblique surface at the upper end is outward. With the author's bone drift or set (of which the carpenter's nail set is the prototype) placed on the trochanteric end of the graft, the graft is now driven into the iliac mortise. In this manner, its trochanteric end is made to slide along the trochanter gutter and its proximal end to penetrate the mortise of the ilium by means of blows of the mallet upon the bone set.

Graft No. 2 is put in by precisely the same technique. The firmer the grafts are driven into the iliac mortise, the closer do

they hug the bottom of the trochanteric gutter because of the obliquity of the cut end of the iliac end of the graft. This plan

Fig. 4a. Same case as in Figure 2. Fusion resulting from iliac bone graft. Note large cavity has been filled with new bone, induced by active bone-forming properties of the bone graft.

of operation automatically immobilizes the grafts at both ends in a most gratifying way and no immobilizing bone ligatures are necessary, with the exception of those placed to pull the soft parts with incorporated bone fragments over the lower end of the grafts at the trochanteric gutters. It is undesirable to enter the joint which is usually filled with extensive ichor or tuberculous pus, and likely to increase in amount, because of the operative trauma and the unfortunate likelihood of its flowing about the bone grafts.

The bone graft must always be placed in an environment of healthy vascular tissue, when possible, and fluid of any kind about it, particularly pus, should always be avoided. If the soft tissues surrounding a graft become infected, it is very likely to lead to the death of the graft. This is one of the principal reasons why intra-articular work should not supplement the extra-articular grafts in fusion operations.

The soft parts with fragments of the

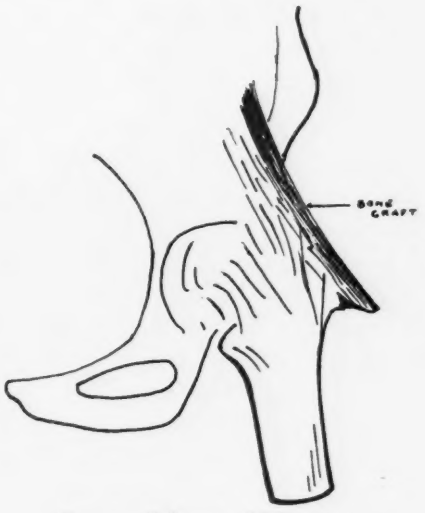

Fig. 4b. Schema of Figure 4a.

trochanter are drawn over the ends of the graft by means of interrupted strands of medium kangaroo tendon. The gluteal muscles are carefully drawn about the grafts by means of No. 2 chromic catgut sutures.

The skin is closed with continuous suture of 0 plain catgut. Suture holes and the edges of the wound are puddled with 3½ per cent tincture of iodine.

In three cases a strong graft about 5 inches long and comprising about one-fifth the diameter of the shaft of the femur from the tip of the great trochanter downward was obtained with a pedicle of muscle at its upper end. The lower end of the femoral graft was swung anteriorly on the muscle and soft tissue pedicle at the upper end as an axis until its anterior end came in contact with the side of the ilium. When the desired location on the ilium was thus determined, a flap or trap-door of the outer table of the ilium was turned slightly upward and backward by means of the motor saw and ½ inch osteotome, so that the upper end of the graft (formerly the lower end) could be thrust backward beneath it. Bone fixation ligatures were not necessary as when the graft is tapped with

a few blows of the mallet and bone drift firmly into place, it will not displace.

The Haas or Hibbs procedure is somewhat similar to this method except that Hibbs' method is not truly extra-articular, as both his diagrams and the description of his technique show that the neck of the femur is exposed and the cortex removed. The operation is therefore necessarily within the tuberculous area, which is to be avoided. Furthermore, this technique requires an extensive operative field, wide resection of muscles, and possible shock. The procedure is the most difficult of the three types of techniques presented. The author has so modified this operation that it is extra-articular, but the great trochanter and attached muscles are much more damaged than when the tibial grafts are used. It leaves more unfavorable conditions for a future arthroplasty to restore motion—a possibility which should always be borne in mind in planning such operations. Again this technique furnishes only one graft of weak, thin cortical bone which may fracture. In fact, in one of my three cases, the graft did break (Fig. 6) but united firmly after re-application of a double plaster of Paris spica for 8 weeks.

Fig. 5. Same case as in Figure 1. After extra-articular arthrodesis by two tibial grafts. Note the remarkable bone repair. Density has come back to both pelvis and top of femur. Spaces formerly filled with caseous material are shown to be completely obliterated with the ingrowth of healthy bone. This patient was so completely relieved of all symptoms and had gained so much in weight, that her mother brought her back from Mexico, one year after operation, to request an arthroplasty operation to restore motion to the hip. However, I did not deem this advisable at such an early date.

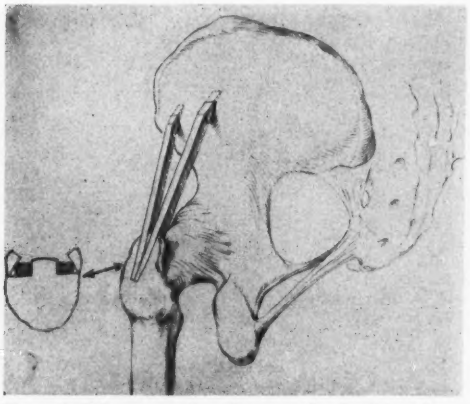

Fig. 6. Diagram showing method of implantation of tibial grafts into great trochanter and side of ilium.

Postoperative Dressing. Postoperative dressings including splintage are very important. Extensive dressings of gauze and sterile cotton are applied, and then a plaster of Paris double spica from just below the umbilicus to the base of the toes on the operated leg, and to the tubercle of the tibia of the opposite leg, in a posture of abduction sufficient to overcome within ½ inch practical shortening, if feasible.

With the plaster still in a semi-plastic state, it is carefully moulded over the operated area, for two purposes: to favor immobilization and to aid in the control of bleeding.

The plaster is removed ten weeks from the time of operation.

Group 2. This group comprises those cases in which the destruction has been so extensive that the trochanter has approximated the rim of the acetabulum to a sufficient degree, so that a sliding graft from the outer table of the ilium including the outer half of its crest, is adequate to reach from the side of the ilium into the trochanter, which is split with 1½ inch osteotome from the superior surface of the neck of the femur outward to receive it. This technique furnishes adequate contact with these bony elements and still allows the surgeon to keep outside of the tuberculous joint. The side of the ilium has already been laid bare by the Smith-Petersen approach and furnishes with the outer half of its crest a very satisfactory graft in that this outer table not only is curved so that it approximates the trochanter and ilium satisfactorily, but also enables the surgeon to secure a very broad graft. This technique necessitates but one incision and is somewhat less difficult of execution and consumes less time than obtaining a graft from the tibia or femur, as described under Group 1. The surgeon, after sizing up the mechanical conditions, may therefore choose this type of technique rather than the other two already described.

Indications for Operation. Extra-articular arthrodesis is indicated at all ages. (1) Whenever there is constant relapse of the abduction deformity in spite of conservative measures to overcome it, such as traction in bed, braces, etc., after long periods of such treatment. (2) If the abduction deformity recurs following Gant's osteotomy, because of the hip not being completely ankylosed. (3) If the *x*-ray reveals destruction of the head or acetabulum or both, even if it is moderate. (4) If there are symptoms of active tuberculosis. The advantages of extra-articular arthrodesis for advanced tuberculosis of the hip with destruction is well illustrated by two contrast cases.

Relative Difficulties of Technique. Where the great trochanter is in close proximity to the rim of the acetabulum, the simplest bone graft operation possible for extra-articular arthrodesis is applicable; the

Fig. 7. *X*-ray showing bone graft at *a*, consisting of great trochanter and upper portion of the femur.

sliding down of a broad graft from the outer table of the ilium, including the outer half of the crest into the split trochanter.

The tibial grafts are next in order of difficulty. The most difficult operation, particularly as to extent of operative field and tissues involved is the Haas or Hibbs technique. A graft of 4 or 5 inches taken from the outer portion of the great trochanter and the shaft of the femur can be used to accomplish an extra-articular arthrodesis. This, however, is an operation of considerable magnitude in that an incision has to be made from just below the crest of the ilium to nearly one-third down the thigh in order to rotate the graft into position.

Caution. A word of caution concerning the execution of these operations is stimulated by recent observation of a lantern slide reproduction of postoperative results elsewhere, in which it was claimed that extra-articular arthrodesis of the hip had been attempted, but with unsatisfactory results in a considerable percentage of cases. The *x*-rays showed that the same inadequate and imperfect technique had been practiced as has been so frequently observed during the past twenty-eight years, when certain men have drawn unfavorable conclusions from their at-

tempts to accomplish extra-articular arthrodesis of tubercular spines, although the operative technique was so poor that a good result could not possibly follow. The most frequent cause of failure has been found to be either too short grafts with inadequate mortising into the elements on each side of the joint, or grafts of too small diameters or too weak to resist breakage. The author wishes again to emphasize the necessity of the graft being of sufficient strength, ample length, with accurate fit and careful extensive mortise into the bony element on either side of the joint. Two illustrative cases with *x*-rays are cited, contrasting the end results of cases with marked destructive tendencies after conservative and operative treatment.

In the maintenance of good digestion, roughage cannot take the place of rest, exercise, good diet, and a generally well-ordered life. . . . Bran is pleasant preventer of constipation, but a sad cure.

TREATMENT OF ACUTE STAPHYLOCOCCIC SUPPURATIVE ARTHRITIS

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THE treatment of acute staphylococcic suppurative arthritis presents one of the most difficult problems in the entire field of medicine. The mortality is high and the end results in the surviving patients are very poor. Nathan[1] stated in 1932, "In contradistinction to the conditions which are inherent in streptococcus and pneumococcus infections, there is in staphylococcus coxitis always massive necrosis, which invariably leads to sequestration and chronic suppuration. The acute symptoms may, if the patient survives the sepsis, subside, but recurrences at longer or shorter intervals are bound to occur so long as the diseased bone remains in situ. I am still convinced that these patients are never cured until the joint is completely obliterated and an end-to-end synostosis between the articulating bones has taken place." The pessimistic views expressed by Nathan are in accord with those of most of the profession.

A survey of the literature reveals that only recently has it been recognized that there is a difference in the clinical course, pathology and requirements of treatment of staphylococcic suppurative arthritis as contrasted with streptococcic or pneumococcic suppurative arthritis. It has never been suggested that there are widely varying forms of staphylococcic suppurative arthritis which are entirely different in their clinical course, pathology and requirements of treatment. With the hope that a better understanding of the clinical course and pathology of acute staphylococcic suppurative arthritis would lead to more effective methods of treatment and more satisfactory end results, an attempt was made to simulate the disease experimentally.*

The knee joints of a series of rabbits were inoculated with 500 million staphylococcus aureus (0.5 c.c. of a saline suspension from an eighteen hour agar slant culture) isolated from cases of acute suppurative arthritis and osteomyelitis. These animals developed typical suppurative joint lesions with marked swelling, local heat and redness of the knee joint region, and flexion contracture of the knee and hip.

In the animal experiments, the factor of host resistance could be regarded as constant, greatly simplifying the interpretation of results. In these preliminary studies, it was found that the lesions produced in the animals tended to be of two distinct types:

1. The animals inoculated with the ordinary abscess producing type of staphylococcus aureus tended to develop markedly invasive local lesions with multiple metastatic abscesses.

2. The animals inoculated with the toxicogenic type of staphylococcus aureus tended to develop mild, non-invasive local lesions with marked toxic degeneration of the viscera. The visceral lesions were similar to those which Rigdon[2] and de Navasquez[3] produced by the intravenous injection of staphylococcus toxin.

The analysis of the results of these animal studies revealed that there are definite requirements which must be met if treatment is favorably to influence the course of the disease.

* In collaboration with Marjory B. Patterson, B.SC., and through the courtesy of Ward J. MacNeal, M.D., Director of Pathology and Bacteriology, New York Post-Graduate Medical School and Hospital, Columbia University.

Requirements of Treatment. Acute staphylococcic suppurative arthritis is a systemic disease. Although the local treatment of the infected joints must be efficient, if future disability is to be avoided, the treatment of the systemic toxemia or septicemia is of greater importance.

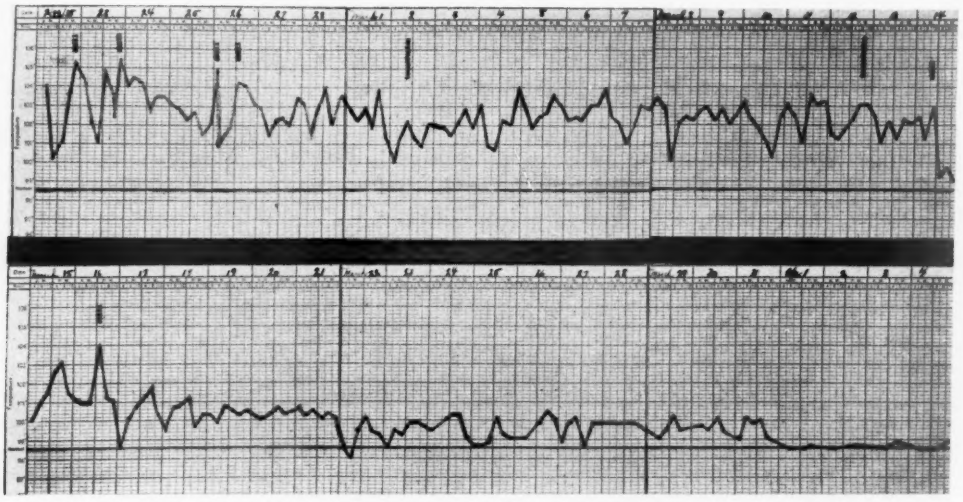

FIG. 1. Temperature chart of case F. M.

Each case must be treated as if both the toxicogenic and abscess producing varieties of the organisms were present because there is no clinical or common laboratory method for differentiating them quickly.

The course of treatment outlined below is compatible with the theoretical requirements established by the experimental studies and has proved to be effective in practice:

1. *Aspiration of the Joint.* The organism infecting the joint must be identified as soon as possible so that the proper treatment can be instituted before permanent damage is done.

2. *Destruction of the Organisms Locally.* The products of bacterial growth are destructive to the synovia and articular cartilages. The irritation of the synovial membrane in the early stages of the inflammation causes an increase in the amount of synovial fluid secreted. This fluid, together with the bacteria and the products of bacterial growth distends the synovia enough to cause further injury and constant pain. The joint is aspirated and flushed with warm normal saline as often as it becomes distended, in some cases, every eight hours. The laboratory immediately prepares a specific bacteriophage from the culture secured at the first aspiration. As soon as this is ready, a quantity equal to one-half the amount of the aspirated pus is instilled into the joint before the aspirating needle is withdrawn. Ninety per cent of the strains of staphylococcus aureus are lysed by their specific bacteriophages. Albee[4] has demonstrated the effectiveness of local bacteriophage therapy in bone and joint infections. The bacteriophage seems to destroy the organism without injury to the synovia or articular surfaces. In this it differs from all chemical substances used to kill bacteria by local application.

3. *Rest of the Inflamed Joint.* It has long been recognized that traumatized joints heal more quickly if they are immobilized. The general condition of the patient improves more rapidly if the pain resulting from the constant motion of the inflamed joint can be stopped without the use of narcotics. In all cases, the suppurative joint is immobilized with a split plaster of Paris cast or traction. This should be done immediately before the joint dislocates, a complication frequently seen in the hip and knee. The immobilization should be continued until the inflammation has completely subsided. As long as joint motion is

painful, there will be a tendency for the patient to hold the extremity in the comfortable position of deformity. Contractures soon develop which unnecessarily prolong the period of disability.

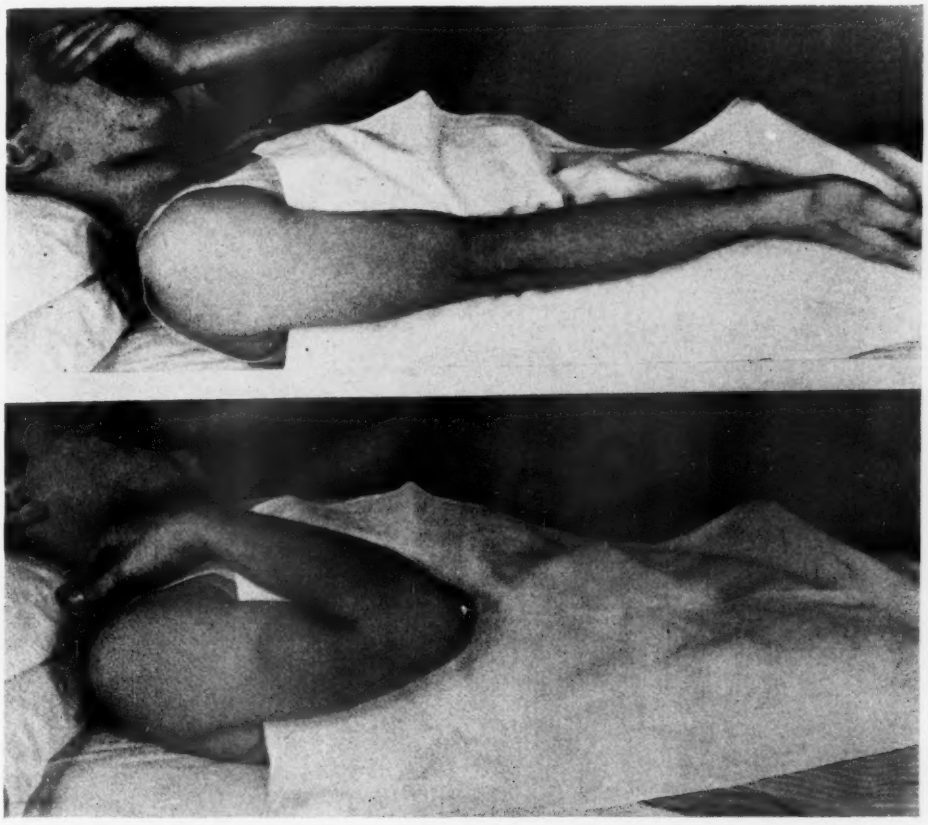

Fig. 2. Range of active painless motion of right elbow four years after the infection.

4. *Prophylaxis against Multiple Metastatic Abscesses.* In most cases of acute staphylococcic suppurative arthritis the involved joint is infected by way of the blood stream. Multiple metastatic abscesses in the viscera, bones and joints are frequently seen. In some cases in which these metastatic, blood-borne foci appear, repeated blood cultures are negative. MacNeal states: "In the animals receiving the injections of bacteriophage, there was a relative protection of the various organs from localization of the infectious agent."[5] He suggests that the bacteriophage aids the body defenses against the bacterial invader by favoring more effective phagocytosis. All patients with acute staphylococcic suppurative arthritis should be given autogenous bacteriophage intravenously according to the method of MacNeal.[6]

5. *Destruction of the Toxin Elaborated by the Infecting Organism.* Both varieties of staphylococcus aureus produce toxin which is absorbed into the blood stream. The anemia which always develops in patients infected with either the toxicogenic or the ordinary abscess producing type of staphylococcus aureus is proof that even the latter variety, which is not classed as an exotoxin producing organism, elaborates enough hemolytic toxin rapidly to destroy the red blood cells. In the experimental studies, it was found that the animals inoculated with the toxicogenic type of staphylococcus aureus developed toxic hepatitis, toxic degeneration of the myocardium, diffuse cloudy swelling of the kidneys with degeneration and necrosis of the epithelium of the glomeruli. Theoretically, specific antitoxin should be given these patients. In the animal studies, the commercial

specific antitoxin which was injected did not protect the viscera of the infected animals against the degenerating effects of staphylococcus toxin. For this reason large doses of vitamin c are given to the patients.

6. *Increase the General Resistance of the Patient.* It is recognized that acute suppurative arthritis is a systemic disease in which the joint inflammation is only an incident. Therefore, the basic principle of treatment of all systemic disease must be observed—build up the patient. Of the measures used, the most important are a high vitamin diet and ample fluids by mouth.

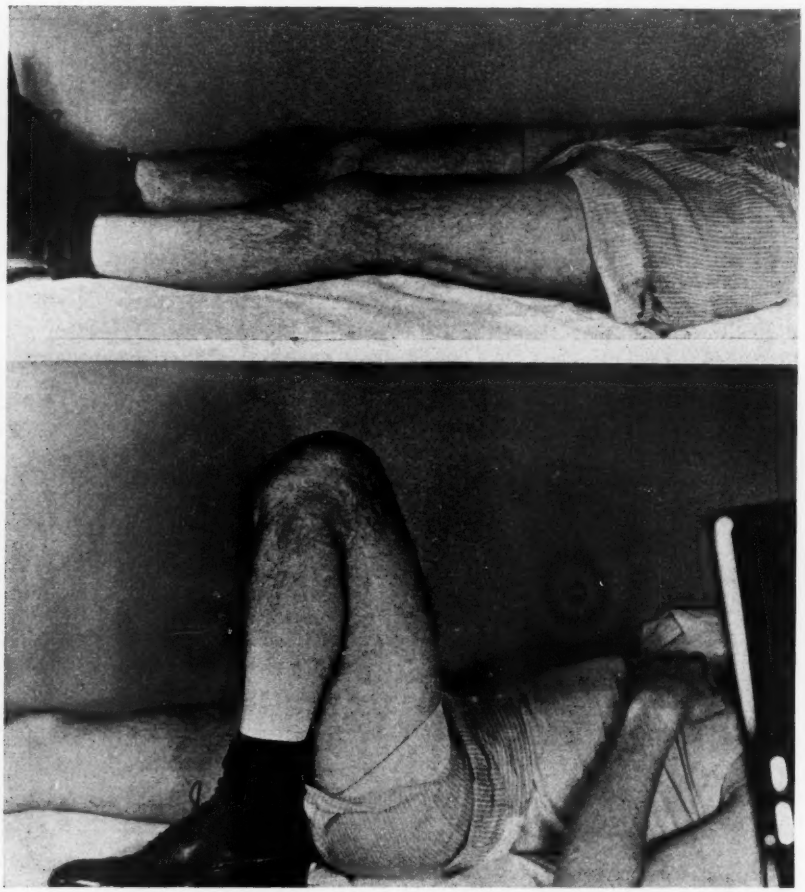

Fig. 3. Range of active painless motion of left knee four years after infection.

the toxin. Lethal doses of toxin could be injected intravenously into non-infected animals along with the proper amount of antitoxin without harmful effect on the animal. In the infected animal, the organism seems continuously to produce such large amounts of toxin that the amount of antitoxin which can be given is inadequate to protect the viscera.

The best available treatment is frequent small blood transfusions. They are most effective if the donor has been immunized against the strain of staphylococcus aureus infecting the patient. In this way the antitoxin titer of the transfused serum can be raised.

Mercier[7] has demonstrated that cevitamic acid inhibits the hemolytic power of

Many of the patients have subclinical scurvy, particularly those who have had a prolonged illness. In the presence of this condition, bone and fibrous tissue repair is slow or absent.[8] The vitamin deficiency need not be marked enough for detection by clinical tests for this delay in healing to take place.[9] For this reason, all patients should receive a high vitamin diet.

7. *Restoration of Motion.* When the temperature has been normal for ten days and there are no signs of localized inflammation around the involved joint, the immobilization should be removed. If two or three days of unrestricted motion do not cause a flare-up of the inflammation, massage and cautious passive manipulation of the joint can be started. If a weight-bearing joint is involved, the patient should now start to walk with crutches. If there are signs of an exacerbation of the joint inflammation at any stage in the treatment, the immobilization should immediately be reapplied. Massage and active and passive manipulation bring about a recalcification of the weakened, osteoporotic, bone adjacent to the articular surfaces, as well as stretch the adhesions limiting motion.[10] If, after three weeks of treatment, the range of motion has not increased, and the *x*-ray shows no bony abnormality which would prevent motion, the joint should be manipulated under anesthesia. Following the manipulation, the massage and active and passive motion must be continued each day to maintain the range of motion secured at operation. The screw-control brace[10] is of great value after manipulation of the knee or elbow.

CASE REPORT

The following case is reported to illustrate the principles of treatment:

F. M., male, age 18, had a sudden onset of fever (104 degrees) on February 8, 1935. At that time, there was no complaint except lethargy, and examination failed to reveal any signs of localized inflammation. The elevation of temperature continued. Ten days later, the patient had a chill and began to have swelling and pain in the right elbow and left knee. Four days later, he was admitted to a hospital. Figure 1 shows the range of temperature during the first week in the hospital; it rose to 105 degrees on four days with four chills. On the fifth day in the hospital, a soft tissue abscess on the left foot, which had been present for two days, was incised.

When the patient was first seen by the author, at the beginning of the second week in the hospital, the right elbow and left knee were immediately aspirated. Before the removal of the needle, the joints were flushed with warm normal saline until the return flow was clear. The elbow was immobilized with a Velpeau bandage and traction applied to the leg. The elbow required no further treatment and the immobilization was removed in five days.

The culture of the thick pus from the knee and elbow showed hemolytic staphylococcus aureus. The laboratory immediately started to prepare an autogenous bacteriophage in broth medium for local use and in asparigen, non-protein medium, for intravenous injection.

The knee was aspirated and washed with saline as often as it became badly distended, every twelve hours at first. After three days, the laboratory was able to furnish autogenous bacteriophage in broth medium. A quantity equal to one-half the amount of fluid withdrawn from the knee was injected at each aspiration (20 to 40 c.c.).

The temperature curve remained at a lower level during the second week of hospitalization, below 104 degrees. During this week, two 400 c.c. direct blood transfusions were given. During the period of hospitalization, four blood cultures were taken, all of which were negative. After seven days, autogenous bacteriophage in asparigen medium was ready for use and the intravenous injections were started. It was given in divided doses every forty minutes, starting with 0.5 c.c. and working up to 10 c.c. This dose was repeated until a total of 200 c.c. had been given. A single dose of 10 c.c. was given on each day following. It will be noticed that there was no change in the level or character of the fever curve for seven days. On this day, the patient had a severe chill following the intravenous injection of the bacteriophage. No phage was given on the next day; the inflammation of the knee had subsided considerably, aspiration being necessary only every twenty-four to thirty-six hours. On the next day, the intravenous phage was started again with a half dose (5 c.c.). Immediately there was a severe chill. It will be noticed that following this, the temperature stayed below 101 degrees and gradually dropped to normal. It was not necessary to aspirate the knee again and recovery was uneventful. During the entire period of hospitalization, the patient was given a high vitamin diet and fluids were forced by mouth.

Figures 2 and 3 show the range of active motion of the right elbow and left knee four years after discharge from the hospital.

Six weeks of daily manual massage and a manipulation of the knee, under general anaesthesia, were necessary to secure this functional result.

SUMMARY

1. The plan of treatment of a case of acute suppurative arthritis must be based upon certain fundamental requirements.

2. These requirements are listed and discussed.

3. A case is reported which illustrates the application of these principles.

REFERENCES

1. Nathan, P. W. Differential diagnosis and the treatment of acute osteomyelitis of the upper end of the femur, involving the hip joint. *Surg., Gynec. & Obst.*, 54: 52, 1932.

2. Rigdon, R. H. Early lesions following intravenous administration of a filterable staphylococcus toxin. *Arch. Path.*, 20: 201, 1935.

3. de Navasquez, S. Experimental symmetrical cortical necrosis of the kidneys produced by staphylococcus toxin. *J. Path. & Bact.*, 46: 47, 1938.

4. Albee, Fred H. Treatment of osteomyelitis and septicemia by bacteriophage. *Rocky Mountain M. J.*, Jan., 1938.

5. MacNeal, Ward J. The infectious organism in osteomyelitis. *J. Bone & Joint Surg.*, 19: 886 (Oct.) 1937.

6. MacNeal, Ward J., Frisbee, Frances C. Bacteriophage service to patients with staphylococcus septicemia. *Am. J. M. Sc.*, 191: 170 (Feb.) 1936.

7. Mercier, P. Mechanism of inhibition of hemolytic power of staphylococcus toxin by cevitamic acid. *Compt. rend. Soc. de biol.*, 127: 297, 1938.

8. Wolbach, S. B. and Howe, Percy R. Intercellular substances in experimental scorbutus. *Arch. Path.*, 1: 1, 1926.

9. Lanman, Thos. H., and Ingalls, T. H. Vitamin c deficiency and wound healing. *Ann. Surg.*, 105: 616, 1937.

10. Preston, Robert L. Restoration of motion in fibrous ankylosis of the knee. *Am. J. Surg.*, 43: 519 (Feb.) 1939.

ORTHOPEDIC CONSIDERATIONS IN THE TREATMENT OF ARTHRITIS*

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THE care of the joints in arthritis cannot be over-emphasized. In atrophic arthritis, particularly, it is common for the clinician to become so submerged in measures directed toward possible etiologic factors and general therapeutic procedures that attention is not given to the care of the joints until they become hopelessly deformed.

Measures directed toward the joints form a basic part of the therapy in all types of arthritis. The procedures indicated depend upon the type of disease and the phase of the condition. They must be based upon a conception of the pathologic process presented by the individual's joints and an appreciation of the effect of available measures upon the process. They should have a specific purpose. If, for example, it is felt that physiotherapy is indicated, the clinician should give definite direction to the procedures that are to be performed, carefully considering the status of the joints, what it is desired to accomplish, and the possibilities and limitations of the particular techniques.

Since the term arthritis includes diseases which show vastly different pathologic processes, it is necessary to consider the therapy under the various types of arthritis. Particular attention will be given to the two major types of chronic disease: "atrophic arthritis" and "hypertrophic arthritis." This classification is used since these terms have been approved by the American Committee for the Control of Rheumatism. It is understood that rheumatoid arthritis, proliferative arthritis, and infectious arthritis are terms synonymous with atrophic arthritis. All of these have justification for their use except "infectious arthritis," since infection has never been proved to be the etiologic factor. Osteoarthritis and degenerative arthritis are other terms given to hypertrophic arthritis.

Septic or pyogenic arthritis will not be discussed since it is the subject of another paper in this issue of the Journal. This condition must be particularly suspected in any acute monarticular arthritis with fever.

It is appreciated that arthritis is a general problem, and it is understood in the discussion of local measures that all other procedures which may influence the disease are performed.

ATROPHIC ARTHRITIS

The clinical picture of fulminating atrophic arthritis is a familiar one: generalized symmetrical involvement, painful swollen joints, progressive deformities, and if severe and uncontrolled, invalidism. It may arise at any age, although more commonly at ages under 40. It may appear as early as the second year of life.

In its worst form, the disease is rapidly progressive. The individual has more or less fever, loses weight even to emaciation, and shows hyperplasia of lymphoid tissue. The latter is particularly true in the disease as seen in children, so-called Still's disease, in which the spleen may be greatly enlarged.

The joints are frequently so sensitive that the patient tends to remain almost constantly in a position of deformity, which in the individual joints is that position characteristic of any intra-articular irritation. (Fig. 1.) There is marked spasm of the deforming muscles with extreme

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atrophy of the antagonistic muscles. The hips tend to become flexed and adducted, the knees flexed, and the feet to go into equinus. In the upper extremity, the shoulders become adducted, the elbows flexed, the forearms pronated, and the wrists go into flexion. The fingers generally show flexion and ulnar deviation except the proximal interphalangeal joints which may hyperextend and become subluxated. (Fig. 2.) Subluxation is common in the hand as it is elsewhere.

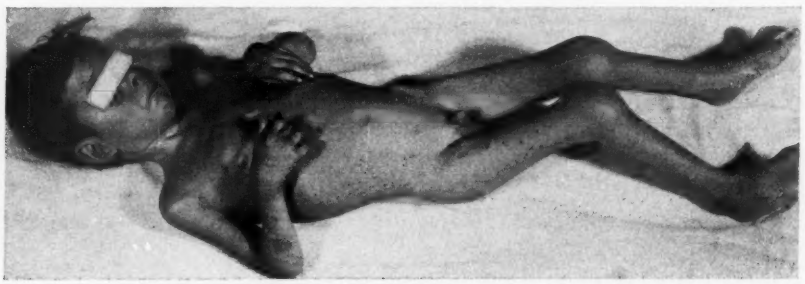

Fig. 1a. Typical deformities of atropic arthritis.

Fig. 1b. Subsequent status of patient in Figure 1a.

The proximal interphalangeal and metacarpophalangeal joints are so typically affected that their appearance may be diagnostic of the disease. It is common for the small joints to be the site of presenting symptoms. The cervical spine is usually involved and shows a flexion deformity, as may the rest of the spine.

The pathologic process in the joints is one of inflammation of the synovia, pannus formation which encroaches upon the cartilage with destruction of the joint surface, and a tendency to either fibrous or bony ankylosis. The bone becomes greatly atrophied; this is the only abnormality that can be recognized in roentgenograms in the early stages of the disease. Later, narrowing of the joint and destruction may be seen.

The active stage of the disease may last for years, but as a rule it gradually becomes quiescent. If deformities have been prevented and joint motion has been preserved, the patient may have very satisfactory function. If deformities have been allowed to develop, subluxation and ankylosis to occur, the individual may be completely helpless, despite the fact that the joints are no longer sensitive.

The joints demand attention from the outset. The local measures indicated depend upon the activity of the process, the joints involved, and the phase of the disease, although they must necessarily be modified by the social and economic status of the individual.

The treatment of the joints is outlined by considering the local disease. The joints primarily show inflammation. Inflammation is ideally treated by rest, and atrophic arthritis is no exception. The joint, however, by its anatomic and physiologic structure modifies the usual dictum of absolute rest in inflammation. The cartilage demands motion. A normal joint, if immobilized for a long period, becomes stiff and the cartilage degenerates. The injury to the cartilage from prolonged fixation in atrophic arthritis is increased by muscle spasm which jams together the opposing surfaces of the joint in a fixed position. Secondary considerations are the marked atrophy of the bone which may secondarily affect the cartilage, and the atrophy of those muscles which oppose deformity.

Considering the above factors, we may evolve the basic principles in the care of the joints: local rest, the prevention of deformities, the maintenance of motion, the minimizing of atrophy of those muscles opposing deformities, and measures to relieve pain. Rest, general and local, is probably the most important known therapeutic agent. It is likely that if we would treat the disease by rest in the early phases with the same radical attitude which exists in the treatment of tuberculosis, most of the tragedies from the disease could be averted. In the acute phases rest to the joint is best obtained by some form of immobilization which reduces muscle spasm

A B

Fig. 2. Deformities of the hands in atrophic arthritis. A, note subluxation of metacarpophalangeal joints, atrophy of bone, and narrowing of joint spaces.

and prevents deformity, yet allows some motion each day as indicated. Movement of the joint is essential to prevent adhesions and ankylosis.

Ordinarily the position for immobilization in the acute phase closely approximates the optimal position for ankylosis. The desired attitude in ankylosed joints varies as to

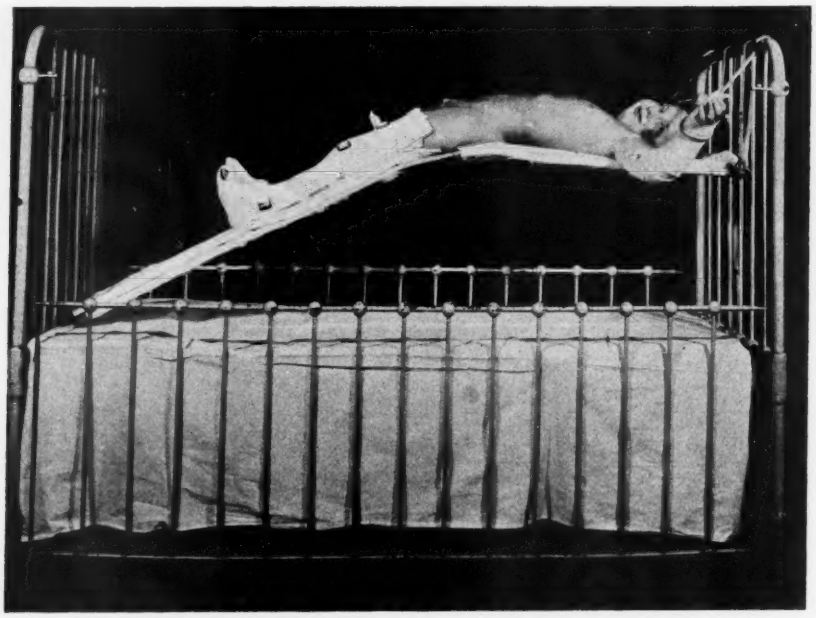

Fig. 3. "Ready for the night." Bivalved casts hold the extremities in positions opposing deformity. Convexity of Bradford frame is too much for an adult.

One method of preventing deformities and obtaining local rest is the use of splints or bivalved removable casts of plaster of Paris or other materials. The parts should be immobilized in a position opposite to that of the anticipated deformity, except for the elbow which is best placed at approximately a right angle. (Fig. 3.) The ideal position of immobilization of the upper extremity maintains the arm abducted at the shoulder and in external rotation, with the elbow held at a right angle and the forearm in supination. The wrist should be in dorsiflexion with the hand neutral as to radial and ulnar deviation, and the fingers slightly flexed, particularly the proximal interphalangeal joints. In the lower extremity, the hip should be extended, neutral as to rotation and in a little abduction, perhaps 15 degrees; the knees should be extended, but not hyperextended, with the foot at a right angle, and neutral as to pronation and supination.

If ankylosis is imminent, the joint must be in the optimal position for function.[1] the occupation and status of the individual and as to whether the involvement is symmetrical. In the upper extremity they should ordinarily be in the position which allows the hand to approach the mouth without elevating the scapula, namely about 65 degrees abduction, 45 degrees flexion, and 35 degrees internal rotation. Ordinarily the shoulder does not become fixed in atrophic arthritis. If one elbow alone is stiff, the best position is usually at 100 degrees, that is, extended 10 degrees past a right angle. If both elbows are fixed, one should be just past a right angle, the other less than a right angle so that the mouth can be reached. The position of the wrist should be in dorsiflexion, neutral as to pronation and supination; the fingers should be in such position that apposition to the thumb may occur.

In the lower extremity, the position depends upon the future habits of the patient. If he is going to be in a sitting position for most of the time, the joints should be in more flexion. As a rule the hips

should be in 20 to 30 degrees flexion, 15 degrees abduction, and neutral as to rotation. The knees should be in a position of 10 to 20 degrees flexion, the foot in slight equinus, neutral as to inversion and eversion. A little pronation is preferable to supination. If more than one joint is stiff in the lower extremity, the position chosen for one depends upon the other.

Ordinarily, in arthritis, one need not be concerned about too little flexion with ankylosis, but rather the prevention of too much flexion.

If the patient seen during the acute phase already has deformity, it should be corrected gradually, not forcibly. With deformity or marked muscle spasm, we frequently use counterbalanced traction (Fig. 4) for immobilization and the instigation of motion.[2] Such traction is particularly helpful in the lower extremities, in which instance, a modified Thomas splint with Pierson attachment is used. The apparatus must be accurately balanced so that the patient may obtain motion with the least effort and the slings must be adjusted in order to prevent subluxation of the joints.

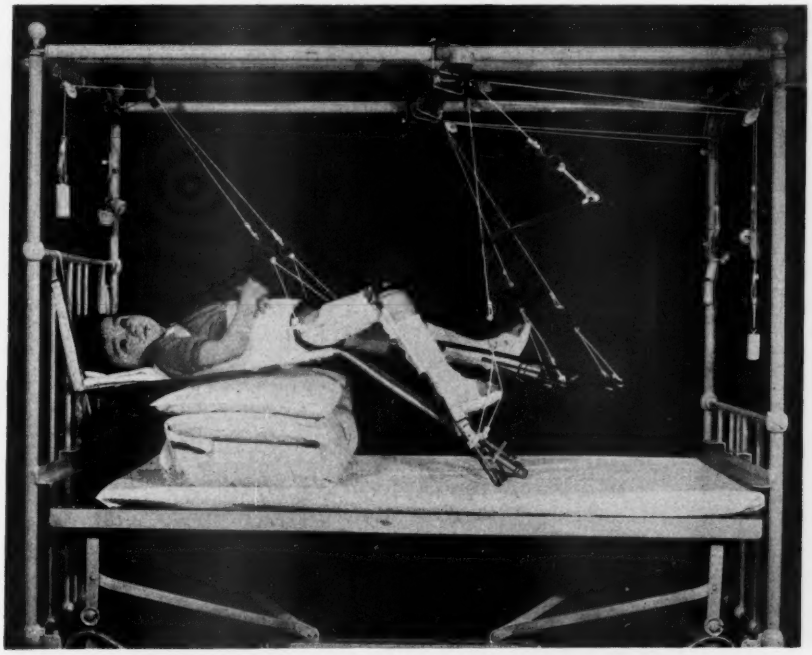

Fig. 4. Couterpoised traction for lower extremities. Patient has the two extremities in different positions, illustrating possibilities of motion.

Traction is started in the line of deformity, and combats muscle spasm, thus relieving the pressure of one joint surface upon the other. Movement of an active type can therefore be started in the apparatus with less discomfort. Between periods of exercise, and particularly at night, the apparatus is locked to immobilize the joints in the best position obtainable. Those motions are stressed which are opposite to the deformity, and attention is given to the muscles which oppose the deformity. If the disease is very active, the individual may not be removed from the apparatus until this can be done painlessly. The degree of sensitivity controls the relative amount of immobilization and activity in the apparatus. At the start the parts are immobilized except for one or two periods during the day, when gentle active motion is performed, guided by the patient or a second person, avoiding discomfort so far as possible. If the joint is very sensitive, each motion is carried out only a very few times at the start. Later the apparatus may be left free for motion at any time except at night, and the individual may carry out increasing activity. The parts, when not

being exercised, should be kept in the corrected position the major part of the time, even when the apparatus is not locked in

Fig. 5. Controlled active exercises in Hubbard tub. Shape of tub allows free motion of extremities.

position. This can be easily managed by the patient due to the counterbalanced arrangement.

Attention must be given to the spine, including the cervical portion, if it is involved. A Bradford frame is frequently necessary, but if a bed is used, it must be unyielding, firm, and straight. Pillows under the head, which may cause a flexion deformity of the neck must be avoided.

Even if the process is such that immobilization of the types mentioned is not deemed necessary, constant effort must be made to prevent deformity by attention to the position of the parts, and by active exercises. When the disease is not particularly active, immobilization at night and during the rest periods is very helpful.

Physiotherapy. The measures during the acute phase are directed toward the maintenance of motion, combating atrophy in the muscles which are antagonistic to the deformity, and relieving pain. Heat is helpful in allaying discomfort and as a preliminary measure to the exercises. Radiant heat may be used, although moist heat is frequently more soothing in very painful joints. The latter may be given either with wet towels heated with a lamp for radiant heat, or by placing the patient in a warm bath such as the Hubbard tub. (Fig. 5.) Prolonged heat is to be avoided.

If the Hubbard tub is used, exercises in water are given, always guided and active in type and directed toward decreasing the deformity. The temperature of the water is ordinarily from 98 to 100°F. It may be a little warmer, although never over 104°F., if the joints are very sensitive; or of lower temperature if the period in the water is to be quite prolonged. The buoying effect of the water is of great assistance, but too long a period in warm water is enervating and must be avoided. The movement of the joints must always be active or guided active, never passive. Passive motion increases spasm and pain, and does not allow as great a range of movement as do guided active maneuvers. The maximum arc of motion that may be obtained without undue discomfort should be secured each day. Ideally the range should be that which can be obtained painlessly, but a certain amount of discomfort is inevitable in most instances if function is to be preserved.

The exercises need not be done in water. If not, they should be carried out by a technician who supports and guides the part through its arc of active motion, assisting in the extremes as sensitivity permits. At first, if the joints are very sensitive, only three or four motions of each joint should be performed, but the exercises should involve all the possible directions of motion at the particular joint, always emphasizing motion opposite to deformity.

"Muscle setting" exercises[3] are very useful in combating atrophy in muscles. (Fig. 6.) They can be done by the patient without assistance and are not painful. Since in "setting," the muscle is contracted with its origin and insertion closely

approximated, the stimulating effect of the exercise is greater than would otherwise be the case. These exercises are particularly

Fig. 6. Quadriceps setting. Phantom photograph with quadriceps relaxed and after "setting." Note shift of black dot over the patella and double contour of thigh.

helpful in the instances of the quadriceps and gluteus maximus.

Massage after the application of heat is a usual measure in conjunction with exercises and should be directed toward the atrophic muscles. Direct massage over sensitive joints is contraindicated.

If it is suspected that the exercises are too strenuous and are increasing sensitivity, they may be temporarily diminished in amount to determine whether they are an irritating factor. There are certain days when the joints are more painful than

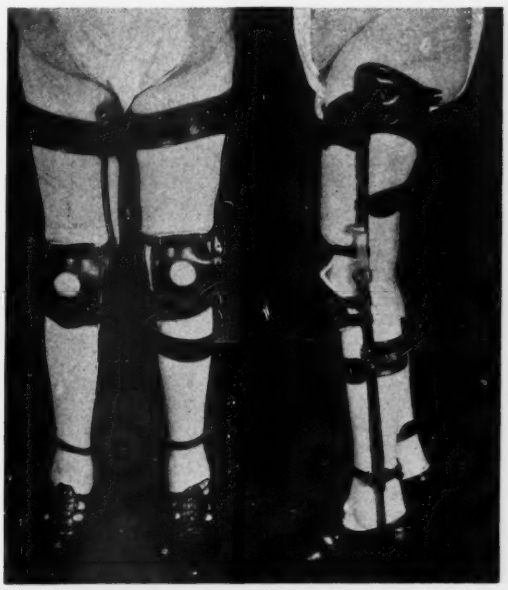

Fig. 7. Walking with caliper braces after flexion deformities of the knees have been corrected.

others, and activity on these days should be less. However, a certain amount of movement must be carried out, and rarely should a day pass without some motion. An accurate record should be kept of the arc of motion existing in the various joints and particular effort should be expended in maintaining it.

The correction of deformities and care during the very active phases are performed best in an institution. Once progress is being made and deformities are corrected, it is frequently possible to carry on at home. Some one in the household can usually be taught by the physiotherapist to guide the exercises twice a day. However, these must be checked at regular intervals by the clinician and the physiotherapist. The patient can carry out some of the exercises himself, but many require help and supervision. Ideally a trained physiotherapist should supervise the exercises at all times, but in practice, they must be done in such an amount that some one living with the patient should be able to assist with them. Immobilization is prac-

ticed at home as indicated as long as there is activity.

As the process becomes quiescent, exercises become more strenuous. Synovial thickening, sensitivity, and the general clinical picture, as well as laboratory determinations, are indices of activity. Walking must be attained gradually, and not before the muscles are strong enough to carry out their function. A therapeutic pool is of assistance when walking is started. Various supports may be necessary, such as caliper braces (Fig. 7) and crutches. Care should be given in the choice of shoes and frequently the feet must be protected by steel plates or flexible pads made in the form of an insole with the supporting factor either of felt or of sponge rubber. If deformity has not developed and motion has been preserved, the problem of rehabilitation may be relatively simple. Progress must be slow.

The Correction of More Persistent Deformities. If the patient has deformities which cannot be corrected by counterpoised traction and active measures with strengthening of the antagonistic muscles, various other procedures are available. Wedging casts may be used. If properly constructed, this type of cast may be bivalved so that periods of motion may be allowed each day. If the cast is of a type that cannot be removed for motion, it should be used for relatively brief periods, and rarely for over ten days unless the disease is quiescent.

Heavy traction may be desirable including skeletal traction. The traction must be in the line of the deformity, changing the direction as the deformity decreases. In flexion deformities of the knee with subluxation, an excellent method is to apply traction with two Kirschner wires, one through the upper end of the tibia to which traction is applied in the anterior direction, and the other through the distal end of the tibia or os calcis with traction in the longitudinal axis of the tibia.

Gentle manipulation under anesthesia is occasionally indicated, both to correct deformity and to attempt to increase the range of motion. Ordinarily it should not be done except in the arrested stage, although occasionally it is desirable during periods of mild activity. Immobilization combined with guided active exercises are the important features after any corrective measures.

Operative Procedures. Various operations may be necessary to correct deformities. Plastic procedures involving the capsule of the joint and other contracted structures may be indicated. In the knee, posterior capsuloplasty, as described by Wilson,[4] may be helpful, and, if indicated, may be combined with skeletal traction as mentioned above. Division of the fascia lata and intermuscular septa may facilitate the correction of flexion-abduction deformities of the hip, as may division of the iliotibial band and adjacent septum[5] aid in correcting flexion contractures at the knee and knock-knee.

Osteotomy may be indicated either to shift the available range of motion to an improved functional position or to place an ankylosed part in an improved functional attitude. For example, osteotomy may be done to correct a flexion deformity of the knee or wrist. If there is marked subluxation of the tibia, it may increase after osteotomy, although the operation has the advantage that, if there is knock-knee, it may be corrected at the same time.

When joints have become ankylosed and motion is imperative to satisfactory function, arthroplasty or other procedures contriving to develop motion may be done in the quiescent stage. Arthroplasty is most desirable in the hip, knee, elbow, finger, and metatarsophalangeal joints. Although results from operation upon the other joints mentioned are uniformly more successful, some operative procedure to develop motion in the hips is almost imperative when both hips are stiff. Arthroplasty[6] of the hip has become a more dependable procedure than formerly. Pseudoarthrosis as described by Jones may be the elective method of obtaining movement, particu-

larly if an arthroplasty has failed. Occasionally a pseudoarthrosis on one side and an arthroplasty on the other may be chosen as the desirable combination. The result of any operation designed to develop motion in arthritis depends not only on the operative procedure and the postoperative care, but the mental attitude of the patient. In choosing the indicated procedures this must be carefully considered.

Various other measures may be indicated. Synovectomy is occasionally desirable in the knee in instances where the arthritis is quiescent and where there is marked synovial hyperplasia and effusion which is mechanically interfering with function. The original contention that synovectomy may remove a secondary focus of arthritis has not been substantiated. In all operative procedures, aftercare and physiotherapeutic measures are as important as the operative procedure itself.

Proper attention to the joints during the acute phase reduces the number of surgical procedures to correct deformities to a minimum.

Spondylitis Ankylopoietica. The relationship of spondylitis ankylopoietica to atrophic arthritis is debatable. The spine may be involved alone (von Bechterew) or in association with the shoulders and hips, the so-called spondylitis rhizomelique of Strumpel-Marie. Occasionally other joints of the extremities are implicated in a process similar in all respects to atrophic arthritis. It would seem that the various types of atrophic spondylitis are variations of the same disease, and that they are all related to atrophic arthritis. The unusual calcification of the ligamentous structures and the particular areas affected by the disease suggest other possibilities. Atrophic spondylitis is essentially a disease of the male, appearing in this sex nine times as frequently as in the female.

The disease is characterized by pain in the back with radicular distribution and muscle spasm limiting motion of the spine. There is early loss of chest expansion which is a diagnostic feature of the disease. Uncontrolled, the spine develops a progressive flexion deformity with marked kyphosis, ankylosis of the spine and ribs, with secondary disturbance of visceral function due to mechanical interference. In the early stages of the disease, roentgenograms show marked atrophy of the involved bones. Later there is fusion of the spine with a typical smooth calcification of the spinal ligaments. The sacroiliac joints are frequently the first joints to fuse.

In those instances when the spine and ribs alone are involved, if deformity is prevented, the spine becomes fused in a good position, diaphragmatic breathing is adequate, the pain disappears, and a very satisfactory functional result is the outcome. Prevention of deformity is accomplished by sleeping on a Bradford frame or a shell of plaster, the use of a long spinal brace, and exercises to combat deformity. If the back is already deformed, and ankylosis is not present, the frame should be bent to follow the maximal correction at the time, and gradually extended as greater correction can be obtained. Occasionally general anesthesia may be given and the spine slowly extended over a period of half an hour by gradually changing the contour of the surface upon which the patient lies. Shells may be applied following. At no time should forced manipulation be used. Where other joints are involved their care is the same as that in atrophic arthritis. "Deep breathing" exercises are very important at all times.

HYPERTROPHIC ARTHRITIS

The treatment of the joints in hypertrophic arthritis is best approached by considering the disease as primarily a phenomenon of "wear and tear," possibly associated with vascular changes and disturbed blood supply to the bone subjacent to the cartilage. The articular cartilage becomes thin and fibrillated. There is reaction at the synoviocartilaginous junction with irregular proliferation of cartilage and subjacent calcification, the so-called

hypertrophic spurs. It may be interpreted as a normal degenerative process which appears in varying degrees at variable ages, modified by intrinsic and extrinsic factors. These changes are greatly increased by mechanical strain or previous trauma which interferes with the mechanical efficiency of the joints. They become significant when they are pronounced in degree and provocative of symptoms. In discussion of therapy no distinction will be made between hypertrophic arthritis and chronic traumatic arthritis.

Bothersome symptoms are much more common in the weight-bearing joints for obvious reasons, particularly the spine and the knees. The hips are less frequently implicated, but the most disabling form of hypertrophic arthritis occurs at this site, the so-called morbus coxae senilis. Frequently the first visible evidence of the senescent type is the so-called Heberden's nodes adjacent to the terminal interphalangeal joints which are diagnostic of this type of arthritis.

Generally the symptoms are of intermittent type. Marked roentgenographic evidence of hypertrophic change may be unaccompanied by symptoms. The pain is probably associated in many instances with irritation and injury to the synovia at the juncture with the hypertrophic process. The threshhold of pain in the particular individual is a factor in the severity of discomfort. When the spine is involved, there may be an associated radiculitis from irritation of the spinal nerves. Symptoms are much more common in obese individuals and where traumatic and mechanical factors are outstanding in the picture.

If the symptoms are acute, the patient must be relieved of discomfort. Rest, heat, massage, and other physiotherapeutic measures are very helpful in this regard. Ordinary radiant heat from an inexpensive lamp using either carbon or tungsten filament is very useful; some prefer diathermy, particularly for the spine. The amount of rest indicated depends upon the discomfort. Rest need be only temporary. Often proper support to the part is all that is necessary.

The next consideration is that of modifying those general and local factors which are provoking the symptoms. In this instance, obesity becomes a fundamental orthopedic consideration; the more weight, the more stress in weight-bearing joints. Irritation from undesirable mechanical factors must be removed in so far as possible. If the patient has symptoms in the knees, associated with genu valgum, the stress on the joints may be reduced by such factors as a lift to the inner side of the heels of Thomas type, or plates for support of pronated feet, which are frequently an associated finding. The heels of the shoes should be of the correct height, based upon the tightness of the heel cord. Granting that a low heel gives a broad base and would seem to be ideal as far as the stability of the knee is concerned, it provokes irritation rather than relieves it, if the heel cords are tight. Frequently pain behind the knee is relieved by elevation of the heels of the shoes, as may be pain under the ligamentum patellae when hypertrophy of the fat pad exists.

Temporary support to the knees is usually indicated. The simplest is an elastic bandage starting well below the knee and going well above the joint. The efficiency and comfort of such support is increased by a horseshoe of felt extending circularly above the patella and well below the joint line, and a broad flat piece of thinner felt behind the joint. The elastic bandage should be at least 4 inches wide and in large individuals, 6 inches wide. If more than temporary protection is desired, an elastic knee cap of good body going well above and below the knee, split in front with eyelets, lacing, and a tongue of chamois, reinforced with strips of leather at the sides, is a very good method of support. The ordinary short elastic knee cap is of little use. If more rigid protection is desired, such apparatus as the Jones knee cage or any of its modifications, and occasionally a caliper brace

are useful. Frequently it is necessary to add a single caliper upright to the shoe in the "cage type" of brace to keep it in position. The support of the knee under normal circumstances is largely dependent upon the quadriceps muscle. Although extreme muscle atrophy is characteristic of atrophic arthritis, not hypertrophic, any painful lesion of the knee causes a reflex atony of the quadriceps and secondary atrophy. To restore the functional capacity of the knee, the quadriceps must be returned to its normal power.[3]

The simplest method of developing quadriceps power is "setting" the muscle with the knee in extension. This must be done on a regular schedule and to a point of just approaching fatigue. Massage and other exercises which do not induce pain or trauma are helpful. Walking with a weak quadriceps does not increase its power, if it is unable to carry out its function. It merely increases the disability.

In arthritis of the spine, support is frequently indicated in the form of a back lace corset or a brace, either of "low back" type or a long spinal brace, depending on the site and extent of the process. Postural factors which are producing strain should be corrected. In postural training the first step is to teach the individual how to assume a better posture. In practice the best approach is to have the individual stand against the wall with his feet a few inches from the baseboard, and teach him to tilt his pelvis by retracting his abdomen and contracting his gluteal muscles. Often the contraction of these particular muscles is taught better in the recumbent position before assuming the erect one. As soon as the back can be flattened the individual shifts from the wall, retaining the desired position. This is repeated until he can assume a good attitude independent of the wall. He is then allowed to relax his gluteal muscles and walk with his abdomen retracted, gradually eliminating the tenseness which exists at the start. Accessory exercises are given to strengthen the abdominal and gluteal muscles as indicated. In lesions of the cervical spine, stretching with heavy traction combined with radiant heat and massage is very helpful. Occasionally a Thomas collar may be used.

Morbus Coxae Senilis. Severe hypertrophic arthritis of the hip with deformity of the head of the femur, so-called morbus coxae senilis, is one of the most difficult lesions to relieve. It is particularly bothersome if both joints are involved. The hip develops a flexion-adduction, external rotation deformity with marked limitation of motion and pain in the hip and the knee.

Various conservative measures of simple type may give considerable relief. A raise to the heel on the involved adducted side balancing the apparent shortening may change the apposition of the weight-bearing surfaces and relieve trauma to the hypertrophic spurs. Non-traumatizing exercises should be given to strengthen the abductors and extensors of the hip, particularly in the form of muscle-setting exercises.

Rest, of course, in an essential agent. Occasionally being off the feet for a few days allows a subsidence of symptoms so that other conservative measures are effective. The temporary use of crutches or a cane is often indicated. Occasionally traction at night, using a removable stocking held by an elastic bandage with weight on a pulley over the foot of the bed, is useful. Removable spicas may be indicated for support.

Operative Procedures. Except in the case of the hip, operative procedures are not often indicated in hypertrophic arthritis. In the hip acetabuloplasty[7] with excision of the anterior capsule may give relief and is particularly helpful where the condition is bilateral. Some form of arthroplasty may occasionally be desirable. In instances where the lesion is unilateral, fusion of the hip may be the procedure of choice.

Occasionally a particular hypertrophic spur may warrant excision. Such a process was one on the coronoid process of the ulna which impinged on the head of the radius with considerable pain and dis-

ability. Removal gave complete relief from symptoms. Various other procedures may be indicated depending upon the condition present: removal of joint mice, synovectomy for so-called villous arthritis, and so forth. Rarely is it desirable to fuse a spine, and, in general, surgery does not have any considerable place in the therapy of hypertrophic arthritis except in the hip joint.

MISCELLANEOUS CONDITIONS

In addition to the two major types of chronic arthritis, consideration must be given to various other lesions of the joints and diseases simulating arthritis. In many of these conditions there is disagreement in the literature both as to the terminology that should be employed and the type of pathologic process present. The terms arthralgia, neuralgia, neuromyositis, fibrositis, toxic arthritis, all come in this category. What might be called "toxic arthritis" by one clinician, might be called "fibrositis" by another, or "arthralgia," which is merely saying there is pain in the joint, by still another. The actual disease in certain vague intermittent pains referable to joints is not determined. Certain conditions are definite in type as determined by the etiologic factor or the pathologic process and local manifestations. Among these may be listed tendinitis, bursitis, traumatic arthritis, gonococcal, syphilitic, and hemophilic arthritis. Idiopathic hydrathrosis may be questionably included in such a group.

In all instances of symptoms in joints and extremities of doubtful type, particular attention must be given to mechanical factors which may enter into the picture. Pain in the feet is more commonly due to foot strain than other causes. Contracted gastrocnemii may provoke pain in the calves and knees. Contracted fascia lata and posterior structures of the thigh may incite pain in the lower extremities and back. Postural factors are the most common cause of backache. These and other possibilities must be analyzed before the diagnosis is made.

At the present time we classify a certain number of joint manifestations which we cannot otherwise differentiate under the term "toxic arthritis," realizing that it is a very questionable group. We include under such a tentative diagnosis, involvement of a single joint or a few joints with definite physical findings and occasionally instances of multiple joints with few positive findings. Certain of these are mild or early instances of atrophic arthritis and this possibility is always considered. They should be treated as atrophic arthritis if the general picture, the clinical examination, and the laboratory findings are in any way suggestive. Rheumatic fever and other clinical entities are likewise considered before placing the individual in this tentative group. It is realized that as our knowledge of arthritis increases, cases will be removed from such a "grab bag" as toxic arthritis and accurately classified.

Under this heading we place the arthritis of children which involves a single joint, and occasionally two or three joints, which does not materialize into generalized atrophic arthritis, although it may be an atypical manifestation of the latter. Such a disease is relatively common in children. At the Children's Hospital, Boston, during the past ten years, arthritis of a single joint has been found to be much more likely of nonspecific than tuberculous origin.

It is suggested in many instances that focal infection or intestinal disturbances are related to these joints. However, we avoid the term infectious arthritis in such instances, as this would merely confuse this type with outspoken atrophic arthritis. We would suggest, however, that the use of the term infectious arthritis is more nearly applicable in many of these patients than its more common use as synonymous with atrophic arthritis.

Therapeutically the care of such joints, after general measures such as attention to focal infection, dietary régime, and bowel management, depends upon the

local manifestations. If the process is quite acute, as frequently is true in children, relief of spasm and deformity by traction, physiotherapy, with particular emphasis on guided active motion, and immobilization in the corrected position by bivalved plaster casts are basic features of therapy. Occasionally the recovery is slow, but ordinarily complete. A weight-bearing splint may be desirable in the convalescence of a joint of the lower extremity. It is interesting that when the process is prolonged in children, stimulation of longitudinal growth occurs. This is most striking when the knee joint is involved and may amount to ¾ of an inch. When weight bearing is started, increased length must be recognized and the shoe of the opposite side raised; otherwise there is a recurrence of the flexion deformity.

In milder types, rest, a removable well fitting support, and physiotherapy are helpful. Immobilization at night may likewise be desirable.

Fibrositis. How often such a disease occurs is not agreed. There are those who believe it is the common cause of transient joint and "near joint" pains. They interpret acute torticollis, lumbago, and other similar disturbances on such a basis. The presence of symptoms which might be interpreted as fibrositis demands a careful examination of the spine as well as an evaluation of other mechanical factors which might explain the picture.

Using the term fibrositis broadly, we may include such common entities as tendinitis, tenovaginitis, and bursitis, which frequently are confused with arthritis. Tendinitis, which is frequently of the calcareous type, and bursitis may occur in many locations, but the classical site is about the shoulder; the most common tendon involved is the supraspinatus,[8] the most common bursa, the subdeltoid. In cases with acute symptoms, severe pain, which is made excruciating by abduction and rotation, is typical, with point tenderness over the greater tuberosity. The pain is referred over the deltoid tubercle of the humerus. Milder cases show less discomfort, emphasized by abduction and the extremes of rotation. At the onset of acute symptoms, a calcareous deposit may not be demonstrable by roentgenograms, although frequently it is present at this time, indicating that the process is of longer duration than the symptoms suggest. The pathologic process is one of degeneration of the tendon with the presence of a thick calcareous material, and in the acute stage, surrounding inflammation of nonspecific type. The etiology is unknown. Trauma is usually given as an etiologic agent, but other unknown factors must exist. It is common for the same individual to have multiple lesions.

The treatment may be conservative or operative. Conservative therapy consists of the use of a sling in a comfortable position, heat which may be dry or moist (dry heat may increase the pain occasionally), and gentle pendulum motions of the hanging arm with the patient standing in a stooped position. These motions should be quite gentle and active, not passive, emphasizing abduction, rotation, and flexion. In carrying out motions in the stooped position, forward flexion of the humerus approaching a right angle exists at the start, and movements are carried out with surprising ease. To appreciate the position of the arm with regard to the shoulder girdle, it is only necessary to hold the arm in a constant position relative to the scapula and have the individual extend his spine to the erect position. Although rest is the primary therapy, carrying on motion in this fashion is important as otherwise the associated periarthritis may give rise to a painful fixed shoulder.

Frequently operative procedures are indicated. Of these, irrigation with a solution of normal saline using a two needle technique is simple and has been very effective. This method, as evolved by Smith-Petersen and Norton[9] and described by Patterson and Darrach,[10] consists in introducing two large caliber needles, 16 gauge, into the

calcific deposit, forcing the saline under pressure into one needle, which in turn forces the calcific fluid out the other. In a great number of cases in which the symptoms are acute, a considerable portion of the deposit can be thus evacuated. The relief may be immediate and dramatic. Frequently, however, the patient remains quite uncomfortable for forty-eight hours with quite rapid recovery thereafter. In many instances the material cannot be evacuated, in which case the area is repeatedly perforated with the needle and saline forced into the site under pressure to the extent of perhaps 40 to 75 c.c. The arm is then carried through a full range of motion at the shoulder. In these patients the relief is not so striking as where a considerable portion of the material is removed, but it is nevertheless definite. In view of the improvement where the material is not actually removed, it would seem that the necessary mechanism in giving relief is needling and rupturing the wall surrounding the calcareous deposit, thus reducing the tension, and allowing absorption of the substance. In one instance about one-third of the deposit was removed as estimated by roentgenograms. Three weeks later the patient died of an unrelated disease. Examination of the shoulder at that time showed only a tiny deposit remaining and the whole process healing. He had obtained dramatic relief from the irrigation and was back at his work as a dentist five days after the operative procedure. The irrigation may be done under local anesthesia, but it may be more desirable to use a general anesthetic.

The postoperative care in these patients is important and consists essentially of that outlined under conservative treatment. We do not fix the arm in abduction, as it increases the postoperative discomfort; a sling is used for support.

In "frozen shoulders" where the periarthritis has given rise to firm adhesions, manipulation under anesthesia is frequently desirable. The injection of saline in the involved plane, to a point where the deltoid muscle is outlined by the subjacent solution is a good preliminary measure. In the manipulation, the shoulder is carried through a full range of motion, but it must be done carefully, as the humerus can be broken if the bone is atrophic and the adhesions are firm. It appears that the instillation of saline renders the manipulation easier, and the postoperative course less painful, perhaps by the infiltration of the injected saline and the subsequent distention of the tissue spaces. After manipulation, the arm should be placed in abduction and exercises of active type started early. At best these patients have considerable postoperative distress.

Although general anesthesia is almost imperative, if desired, the injection may be done using local anesthesia following which a brief general anesthesia such as evipal may be given for the manipulation.

The other operative procedure available is incision and evacuation of the calcareous material. This procedure is simple and has the particular virtue that indefiniteness is obviated and the process can be seen and the material removed. In our experience, in an acute process, irrigation gives just as prompt relief and shorter convalescence. If the irrigation does not relieve symptoms after an adequate interval, open procedure is indicated.

Gonococcal Arthritis. Gonococcal arthritis may be of frankly septic type in which the organisms can be obtained by smear and culture. In others the organisms cannot be demonstrated and the actual etiologic mechanism is in doubt. The latter type is less severe and more likely to involve multiple joints.

The orthopedic care of gonococcal arthritis has assumed much less importance since medical care has become more effective. Previously, an effective method in those in which the organism could be demonstrated was incision of the joint, irrigation with warm saline for twenty minutes with closure of the joint followed by appropriate after-care. Such care was a combination of immobilization in the

elective position, by either a half-cast of plaster, or preferably by counterpoised traction if the particular joint allowed itself to such traction. Gentle guided active motion, heat, and other definitive types of physical therapy were given as indicated.

The local care of the non-septic type of gonococcal arthritis was essentially the same as that used in the after-care of the septic joint. Immobilization in a position of election with guided active motion each day, and local heat were essential considerations.

With the use of fever therapy of efficient type and sulfanilamide, orthopedic measures have become less important, and surgical procedures in septic gonococcal joints are not ordinarily indicated. However, immobilization in a position of election and guided exercises for the restoration of function of the joint remain important factors in the treatment.

Syphilitic Arthritis. Arthritis from syphilis may occur in either the secondary or tertiary stage. Synovitis due to syphilis is most common in the congenital disease, and the knee is involved most frequently. It is often bilateral. The idea that it is always painless cannot be verified as occasionally the joint may be quite sensitive. The treatment is support as indicated by the distention of the joint and the sensitivity, combined with the specific treatment for syphilis.

Charcot's joint, with disintegration of the joint, pronounced proliferative reaction of the bone, and singular lack of pain is really a neuropathic arthropathy. Adequate support to the part combined with antiluetic therapy is the treatment of choice. Occasionally intrinsic fixation of a given joint is indicated, although it may be difficult to obtain fusion. In certain instances amputation may be desirable.

Hemophilic Arthritis. Repeated hemorrhage into a joint causes marked distention of the capsule, irritation of the synovia with subsynovial scarring and destructive lesions in the subchondral bone with involvement of the cartilage as described in detail by Key.[11]

The joints should be protected during the acute phase, in which the capsule is markedly distended, by immobilization and pressure with an elastic bandage. A posterior shell of plaster is an ideal method of immobilization, with loosening and tightening of the bandage as indicated. Occasionally if the capsule is markedly distended, and the clotting time is not too long, the joint may be carefully aspirated with a fine needle. The needle should be directed obliquely through soft tissues in approaching the joint.

Repeated hemorrhages produce a chronic arthritis with deformity which may be very similar in appearance to the result of atrophic arthritis. Gentle correction of deformities by conservative means and exercises for those muscles opposing deformity may be indicated. Extrinsic support to the joints is occasionally advisable.

Idiopathic Hydrarthrosis. In this condition, the joint is distended by an excess amount of synovial fluid, with singularly little synovial thickening, and usually little or no sensitivity, unless the distention is extreme. Frequently it is intermittent in type (intermittent hydrops) and on a fairly regular schedule both as to duration and interval. It is more common in women. The knee is most often involved. The etiology is unknown, although various theories have arisen, including ideas that it is related to angioneurotic edema, that it is due to an endocrine disturbance, and that it is an allergic phenomenon.

With distention of the joint and secondary relaxation of the capsule, secondary traumatic arthritis may arise. Support and pressure during the acute phase, using an elastic bandage or knee cap, may be helpful, and undesirable mechanical factors should be corrected. Exercises to the quadriceps in the instance of the knee should be stressed. In particularly bothersome cases, synovectomy may be desirable. In swelling of the continuous type, lues should be considered in the differential

diagnosis, as should synovial tuberculosis and other forms of arthritis.

Traumatic Arthritis. Arthritis due to chronic trauma of mechanical and static nature has been considered under hypertrophic arthritis. The treatment of chronic traumatic arthritis, which is the residuum of severe acute injury must be individualized and approached with a consideration of principles previously discussed.

LOW BACK PAIN—SCIATICA

A discussion of this subject requires more space than can be given here. Of proved arthritic entities, atrophic, hypertrophic, and traumatic arthritis may produce pain in the back, with or without sciatic radiation. The actual mechanism of pain in many instances is in doubt, but ligamentous strain and irritation of the apophyseal joints by disease or trauma must be the mechanism in many instances. The importance of referred pain is emphasized by some, particularly with regard to the sacroiliac joints. Fibrositis and myofascitis are likewise suggested as the cause of many pains in the back, but the exact relationship and incidence of such a condition has not been established. Neither has the importance of "articular slips" been proved. Postural and mechanical strain is probably the greatest factor in backache.

Anything which irritates the nerve either in the spinal canal, in the intervertebral foramina, or elsewhere in its course may cause pain with a sciatic distribution. Hypertrophic arthritis or other narrowing of the intervertebral foramina, particularly that through which the fifth lumbar nerve passes, may cause a radiculitis. Hadley[12] has recently affirmed embarrassment of the nerve by subluxation of the apophyseal articulations associated with narrowing of the intervertebral disk.

The relationship of lesions in the spinal canal to pain of sciatic radiation has been emphasized in recent years by Barr,[13] Mixter, and others. Protrusion of tissue from the intervertebral disc may impinge on one or more nerve roots of the cauda equina, producing "sciatica." Likewise, others have pointed out that hypertrophy of the ligamentum flavum[14] may produce a similar picture. These lesions must be suspected in intractable "sciatica."

A thorough attempt should be made to explain the origin of the symptoms with full consideration of the history as well as the physical findings. All mechanical factors must be evaluated both in the back and in the lower extremities. What are the characteristics of posture as they affect the back? Does a significant anomaly of the spine, such as spondylolisthesis, exist? Is one leg shorter than the other? Are the feet pronated? Are the fascia lata and the posterior structures contracted? May the lesions be localized by manipulative measures or palpation? What neurological signs are present? Complete roentgenographic study of the lower spine is necessary. Spinal puncture may be desirable with determination of the total protein and dynamics. Visualization of the spinal canal may be indicated.

The relationship of backache to fatigue, poor health, and other lesions remote to the back must be kept in mind.

Conservative measures are ordinarily indicated before other procedures are considered. If the pain is severe, absolute rest on a firm straight bed with pillows under the knees and physiotherapeutic measures are essential. Support in the form of a backlace corset, a low back brace, or even temporary strapping with adhesive plaster is most helpful. Usually, if sciatic radiation is present, a corset is more useful than a brace. Postural exercises, particularly abdominal and gluteal setting, aid in most instances, as emphasized in the section on hypertrophic arthritis. In fact, adequate support and attention to posture form the basic treatment of the greater number of patients with back pain.

If in "sciatica," the fascia lata is contracted, division may be done, as advocated by Ober,[15] under local anesthesia with

little bother to the patient and in a considerable percentage with marked relief.

We believe that these measures should be tried before more radical procedures are considered including the introduction of lipiodol into the spinal canal to visualize a possible herniation of the disc, unless the protein of the spinal fluid is markedly elevated or the signs are very striking.

SUMMARY COMMENT

Attention to the joints is a basic consideration in all types of arthritis. The local measures are dictated by the type and phase of the disease.

REFERENCES

1. Hench, P. S., and Meyerding, H. W. The results of failure or neglect in the care of chronic infectious (atrophic) arthritis: the characteristic deformities, and their prevention. *M. Clin. North America*, 18: 549–571 (Sept.) 1934.
2. Green, W. T., and Ober, F. R. Chronic arthritis in children. *Proc. A. A. Study & Control Rheum. Dis.*, June 11, 1934.
3. Ober, F. R. Physiotherapy in arthritis. *M. Clin. North America*, 18: 1013–1022 (Jan.) 1935.
4. Wilson, P. D., and Osgood, R. B. Reconstructive surgery in chronic arthritis. *New England J. Med.*, 209: 117–125 (July 20) 1933.
5. Fitchet, S. M. "Flexion deformity" of the hip and the lateral intermuscular septum. *New England J. Med.*, 209: 74–77 (July 13) 1933.
6. Smith-Petersen, M. N. Arthroplasty of the hip. A new method. Read before American Academy of Orthopaedics, Jan. 15, 1939. *J. Bone & Joint Surg.*, in press.
7. Smith-Petersen, M. N. Treatment of malum coxae senilis, old slipped upper femoral epiphysis, intra-pelvic protrusion of the acetabulum, and coxa plana by means of acetabuloplasty. *J. Bone & Joint Surg.*, 18: 869–892 (Oct.) 1936.
8. Codman, E. A. The Shoulder. Boston, 1937.
9. Norton, P. L. Personal communication.
10. Patterson, R. L., Jr., and Darrach, W. Treatment of acute bursitis by needle irrigation. *J. Bone & Joint Surg.*, 19: 993–1002 October, 1937.
11. Key, J. A. Hemophilic arthritis. Annals of Surgery, 95, 198–225, (Feb.) 1932.
12. Hadley, L. A. Apophyseal subluxation. *J. Bone & Joint Surg.*, 18: 428–433 (April) 1936.
13. Barr, J. S. "Sciatica" caused by intervertebral-disk lesions. *J. Bone & Joint Surg.*, 19: 323–342 (April) 1937.
14. Spurling, R. G., Mayfield, F. H., and Rogers, J. B. Hypertrophy of the ligamenta flava as a cause of low back pain. *J. A. M. A.*, 109: 928–933 (Sept. 18) 1937.
15. Ober, F. R. The role of the iliotibial band and fascia lata as a factor in the causation of low back disabilities and sciatica. *J. Bone & Joint Surg.*, 18: 105–110 (Jan.) 1936.

CORRECTION OF CONGENITAL DEFORMATIONS OF THE HAND

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THE surgeon who is confronted with the problem of correcting congenital deformity of the hands is faced with several perplexities; although the diagnosis in most instances may be a simple matter, in the presence of some of the vascular anomalies, diagnosis and treatment will tax the astuteness of those concerned. The surgeon must keep foremost in his mind two problems: (1) that of function and (2) that of appearance. Function should not be sacrificed in order to improve appearance; each case must be considered individually.

It is difficult to make a practical classification of congenital malformations of the hand because of the multiplicity of such conditions, their many combinations and the prevalent lack of knowledge as to their etiology and pathology. Therefore, in this communication terms which are descriptive of the morphologic characteristics will be used.

The basic approach to the study of these congenital malformations is through etiology. Hypotheses too numerous to mention in a paper of this kind have been put forth. Similar congenital malformations of the hands and feet frequently are encountered in examining the same individual; this fact, together with the high incidence of a history of similar malformations in forebears, suggests the possibility that the germ plasm hypothesis of origin of the condition is correct. The work of Bagg demonstrated that congenital deformities may be produced by insult to the germinal cells, that these deformities may manifest themselves in the progeny. In his work mice were subjected to Roentgen irradiation and various anatomic defects of the extremities were inherited by the descendants.

Because of limitation of space, material relative to anomalous vessels, nerves and muscles will be omitted from the following discussion.

SYNDACTYLIA (WEB FINGERS)

As was mentioned earlier, congenital malformations of the hand frequently are seen in association with other anomalies. This is particularly true of syndactylia. Various degrees of webbing of the fingers are found, the union consisting of skin only, of skin and fibrous tissue or of fused bony elements. Anomalous vessels, nerves, joints, tendons and tendon sheaths also are encountered and the various components of the anomaly are to be considered before surgical operation is undertaken.

Numerous operations for the correction of syndactylia have been described, the earlier procedures being directed only at severance of the web. The technique of each of the earlier procedures was based on principles of surgery current at the time the procedure was in favor.

The problem arises as to when operation for syndactylia should be performed. If the web is a simple one that was noted at birth, and distortion of the involved fingers is not present, it is advisable to wait until the patient is older; this will greatly simplify the technical difficulties encountered. However, if the syndactylia is of more severe degree, and considerable deformity already is present, then the end results might be improved by operative intervention in the first year of life, with the understanding that secondary plastic operations are carried out more satisfactorily at a later time. Space does not permit review of the merits of the many operative procedures for correction of syndactylia

which were described by Rudtorffer in 1901, Zeller in 1810, Didot in 1850, Agnew in 1883, Felizet in 1892, Tubby in 1912, Faniel in 1911, Rudulesco in 1923 and Ville Chaise and Jean in 1927, but in their time many of the authorities named improved the technique of surgical treatment of this condition.

Plastic procedures may be used in some of the more simple cases of syndactylia. In the more severe cases, however, no matter what operative procedure is selected, when the web is severed the available skin is inadequate and application of a skin graft is necessary. The extensive scar which followed the older operative procedures also permitted recurrence of the web and other unfortunate sequelae, such as contractures. Some of the older procedures, such as Didot's plastic operation (1850), have been known to result in gangrene of the fingers in those instances wherein the blood vessels had been divided in raising the skin flaps.

To cover the commissure with skin so that a scar will not form is one of the important principles which should be kept in mind. When more than two fingers of one hand are involved, it is best to carry out only one procedure at a time. Kanavel advocated the use of full thickness skin grafts, but the split skin graft method of Blair and Brown has given satisfactory results in our hands.

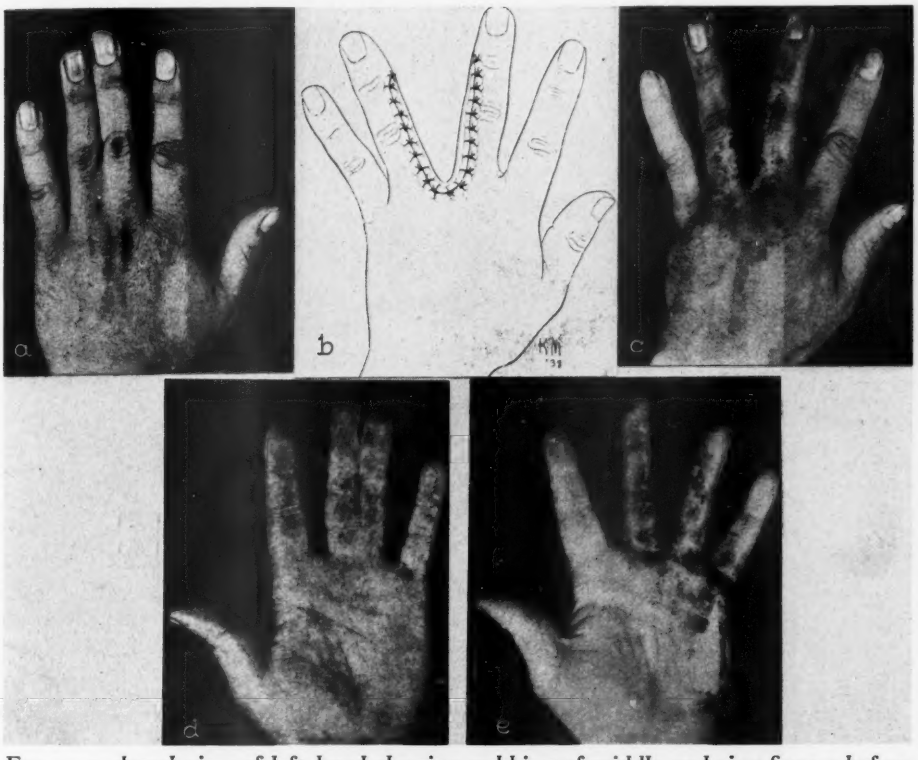

Fig. 1. *a*, dorsal view of left hand showing webbing of middle and ring fingers before surgical intervention. *b*, separation of fingers and split skin graft sutured over denuded surface. *c*, dorsal view immediately after removal of stitches. *d*, palmar view of hand before operation. *e*, palmar view immediately after removal of stitches.

Case 1. A man, aged 30 years, stated that a deformity of his left hand had been present since birth. In an attempt to separate the third and fourth fingers, the web was cut and a flap made on the dorsum of the third finger; a flap also was raised on the volar surface of the fourth finger. These flaps were not large enough to cover the defects and the remaining areas were covered with a split skin graft, which had been taken from the left thigh. The grafts were sutured into place with fine black silk and were perforated with a sharp knife. The wounds were dressed with scarlet red ointment gauze

and a sea sponge dressing was applied to exert pressure. The functional result following this procedure was excellent. (Fig. 1.)

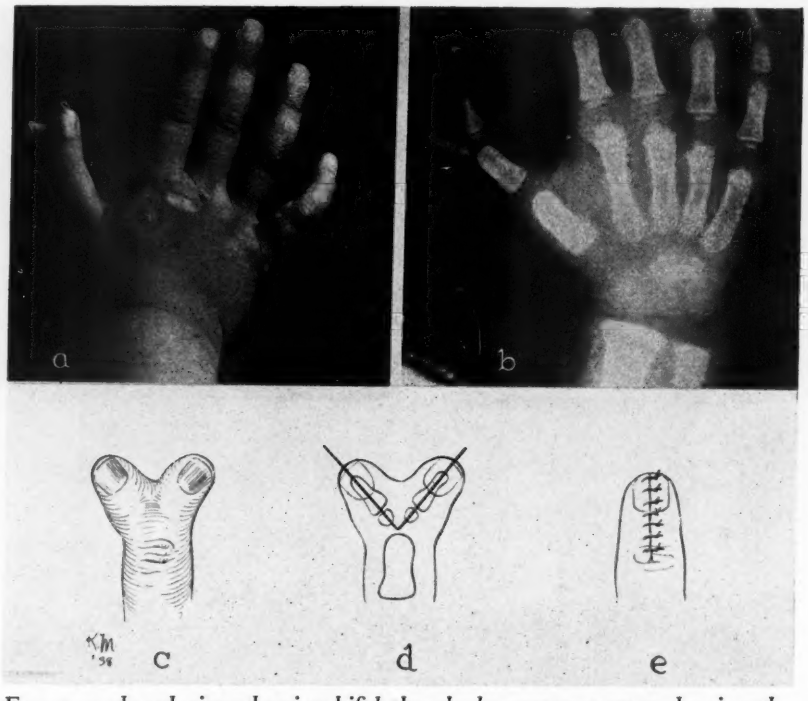

Fig. 2. *a*, dorsal view showing bifid thumb. *b*, roentgenogram showing the two terminal phalanges. *c*, bifid thumb. *d*, wedge-shaped excision through distal phalanges and soft parts. *e*, closure of wound with approximation of the halves of the digit.

In cases of terminal bony syndactylia, division of the terminal phalanx and repair by skin graft is the desirable procedure. Extreme care must be given the blood vessels and nerves because they are often anomalous. The tendons to each finger should be examined carefully and, in the event one or the other tendon is deficient, judgment should be exercised in determining to which finger the tendon should remain attached. A plastic procedure can be carried out later on the digit which is lacking a tendon. Attention must be given to the nails, joints and deficient muscles. Simple division of a fused nail can be carried out along with division of the phalanx. Simple division of the terminal interphalangeal joint does not seriously interfere with function.

POLYDACTYLISM (SUPERNUMERARY DIGITS)

Many attempts have been made to group the various types of polydactylism, but again difficulty is encountered because of the multiplicity of abnormalities. A marginal and a central type can be identified. The marginal form, characterized by duplication of the thumb or little finger, is most common. The condition may arise from bifurcation of the metacarpal bones or merely from bifurcation of the phalanges, in which event syndactylia is an associated condition.

Polydactylism is not infrequently encountered in combination with syndactylia and, more rarely, with lack of development of some portion of the hand. Polydactylism is often bilateral, frequently involves both the hands and the feet and often is associated with other congenital anomalies. The extra digit is usually very atypical in its form and components; the bony components may be duplicated, fused or distorted. Its blood supply, nerves, tendons and joints are often abnormal.

Before any surgical procedure is carried out careful consideration must be given to preservation of function. Due attention must be given to the insertion of tendons

and to the vascular and nerve supply to a part.

An extra digit on the thumb may be better left alone. Any corrective surgical procedure here, without careful consideration, may disturb the circulation and result in gangrene of the remaining digit. Particular attention should be given the intrinsic musculature of the thenar region, as operative procedures might result in a flail digit. It may be best for maintenance of function to transfer the tendon from the extra digit which is to be removed to the remaining digit or even to other portions of the hand. Simple hypoplastic digits are best amputated. The Bilhout-Cloquet plastic procedure has the advantage, in caring for bifurcated distal phalanges, of preserving the attachment to the tendon. This procedure is particularly applicable to the thumb in cases in which a v-shaped median section is removed from the two parts. The incision extends from the middle of the distal part of one rudiment, down below the bifurcation, and back distal to the middle of the other rudiment; the intervening components are removed and the remaining portions of the two rudimentary phalanges are brought together in the median line. The incision may be modified some if one rudiment is longer than the other. (Fig. 2.)

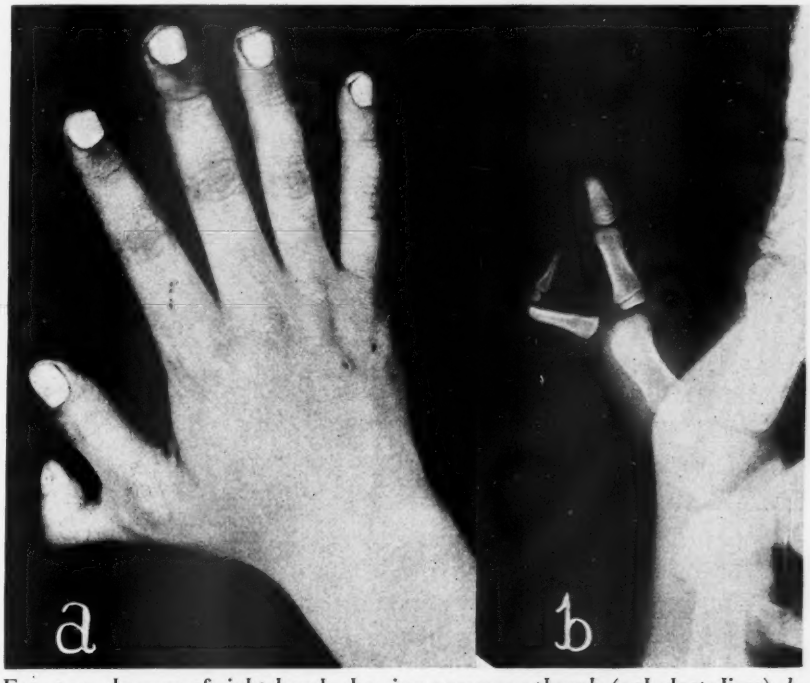

Fig. 3. *a*, dorsum of right hand, showing accessory thumb (polydactylism). *b*, roentgenogram showing two phalanges in the accessory thumb.

Case II. A boy, aged 8 years, complained of an accessory thumb of the right hand, which had bothered him only in a mechanical way. (Fig. 3.) The accessory thumb was amputated at the metacarpophalangeal joint and both appearance and function were improved.

ECTRODACTYLIA (CLEFT HAND, LOBSTER CLAW HAND, CRAB CLAW HAND)

The classic type of lobster claw hand is one without the middle finger and part of its metacarpal bone. Many would limit the term to this lesion. However, every degree of involvement is found; that is, the middle finger alone, or the middle finger and its metacarpal bone, or all components of the middle portion of the hand may be absent. Rudimentary phalanges and metacarpals, of various degrees of development, may be noted.

Various types of plastic procedures can be performed on patients with this condition and considerable improvement of both appearance and function may result. The improvement in function depends considerably on the extent of involvement of

nerves, muscles, tendons and joints. Thus, in cases of ectrosyndactylia, if some digits are absent and those remaining are fused, joint. If the condition is recognized early in life correction can be accomplished by application of proper splints. The more

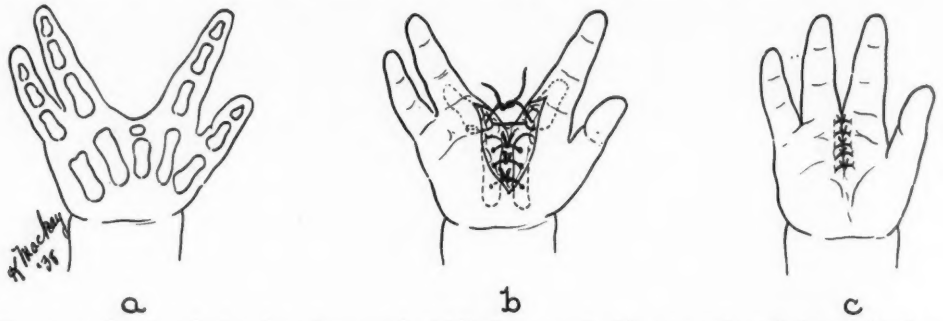

FIG. 4. *a*, claw hand, showing absence of middle finger and wide separation of ring and index fingers. *b*, excision and removal of metacarpal bone and approximation of metacarpal bones by means of three sutures. *c*, approximation of wound resulting in improvement in appearance of hand.

surgical treatment may be contraindicated because of malformation of the component parts.

Operative procedures in these cases are best carried out in several stages. The primary object is to approximate the fingers on the radial and ulnar sides of the hand. If the cleft extends into the palm of the hand, a wedge-shaped incision is made, extending from the middle of the proximal phalanx down through the palm of the hand. After the deeper structures have been exposed by dissection, it may be necessary to resect any anomalous bony fragments in order to permit closer approximation of the adjacent metacarpal bones. The metacarpals and proximal ends of the phalanges are bound together with living suture material such as fascia lata or with some nonabsorbable suture material, and then the tissues are approximated layer to layer. (Fig. 4.)

In those cases of lobster claw hand in which the cleft does not extend into the palm, and the index finger is entirely separate from the thumb, this finger can be transplanted as described by Kanavel.

CLINODACTYLY, DACTYLOGRYPOSIS (FLEXION OF FINGERS)

Clinodactyly is thought to result from some disturbance in the epiphysis, producing malalignment in the interphalangeal

severe conditions, seen later in life, necessitate division of the shortened bands of fascia, possible lengthening of tendon and filling in of the defect by a split skin graft. Congenital contracture of the finger, seen late in life, should not be confused with Dupuytren's contracture. (Fig. 5A and B.)

MEGALODACTYLIA, MACRODACTYLY (GIANT FINGERS)

Hypertrophy of the digits, a rare entity, usually affects the thumb, index finger or middle finger. Giant fingers result from one of two causes: (1) bony overgrowth; and (2) lymphatic and neurofibromatous hyperplasia. If the cause of the anomaly is the type of hyperplasia that has been mentioned, usually an abundance of fatty tissue is present; if the cause is bony overgrowth, there is little or no change in the soft tissues. In the presence of neurofibromatous hyperplasia, the digital nerves have been known to reach 8 mm. in diameter.

If the overgrowth is a result of neurofibromatous tissue, a plastic procedure, in the course of which the hyperplastic tissue is removed, can be carried out in an attempt to improve the appearance of the hand. When the giantism is a result of bony overgrowth, as well as of hypertrophy of the soft tissues, both function and appearance of the hand can be improved by amputation.

Case III. A man, aged 28 years, complained that the left ring finger had been enlarged since birth and that the left index and middle fingers were weak. The family history was negative. General physical and laboratory examinations gave negative results except for the following findings relative to the left hand and forearm: In addition to the enlarged finger, represented in Figure 6A, in the palm of the hand there was a palpable mass which extended into the forearm. Neurologic investigation of the hand revealed both motor and sensory changes consistent with inflammation of the median nerve. The anteroposterior roentgenograms of the hand revealed hypertrophy of the phalanges with evidence of destruction in the interphalangeal joints. There was also exostosis on the ulnar side of the middle phalanx of the middle finger. (Fig. 6B.)

At operation the mass on the flexor surface of the wrist proved to be a neurofibroma; neurolysis was carried out and the wound closed. The giant finger then was amputated at the metacarpophalangeal joint. The report of the pathologists was as follows: "The specimen consists of a finger 13 cm. in length and 2.5 cm. in diameter, characterized for the most part by a marked increase of fibrous and fatty tissue, also hyperkeratosis of the palmar surface of the epidermis. The digital branch of the median nerve on the radial side showed a fusiform neuroma, 3.5 cm. in length and 8 mm. at its greatest diameter, beginning opposite the proximal interphalangeal joint."

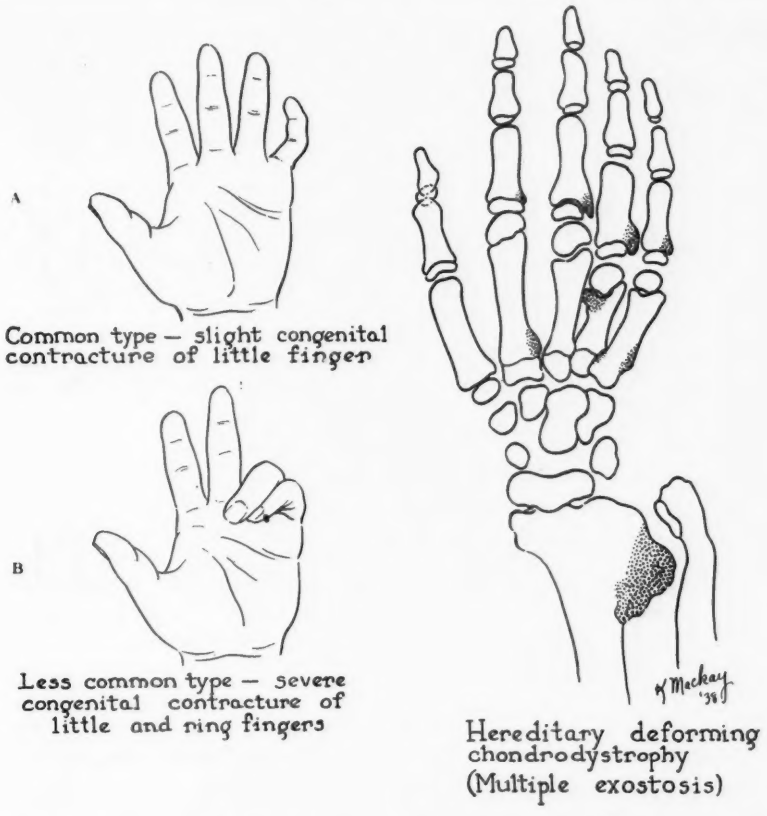
A
Common type — slight congenital contracture of little finger
B
Less common type — severe congenital contracture of little and ring fingers
Hereditary deforming chondrodystrophy (Multiple exostosis)
C

Fig. 5. Congenital flexion of fingers and hereditary deforming chondrodystrophy (multiple exostosis).

CONGENITAL ARTERIOVENOUS FISTULA

Arteriovenous fistula was first described by William Hunter in 1757, when he discussed the clinical features and the disturbed vascular physiologic processes which accompany the condition. Horton[8] has defined an arteriovenous fistula as any abnormal communication between an artery and vein, by means of which arterial blood passes from an artery to a vein without passing through a capillary bed.

Congenital arteriovenous fistulas always have been considered rare. In 1920, Callander reviewed 447 reports of cases of arteriovenous fistula and found only three records of the congenital form. In 1930 Lewis, in reviewing the literature, was able to find reports of only thirty cases, including the six of his own. From June, 1929 to May, 1931 twenty-four patients with arteriovenous fistula were seen at The Mayo Clinic and reports of their cases were made. That this number of cases was encountered in so short a period would suggest that diagnosis has been improved by adoption of newer methods.

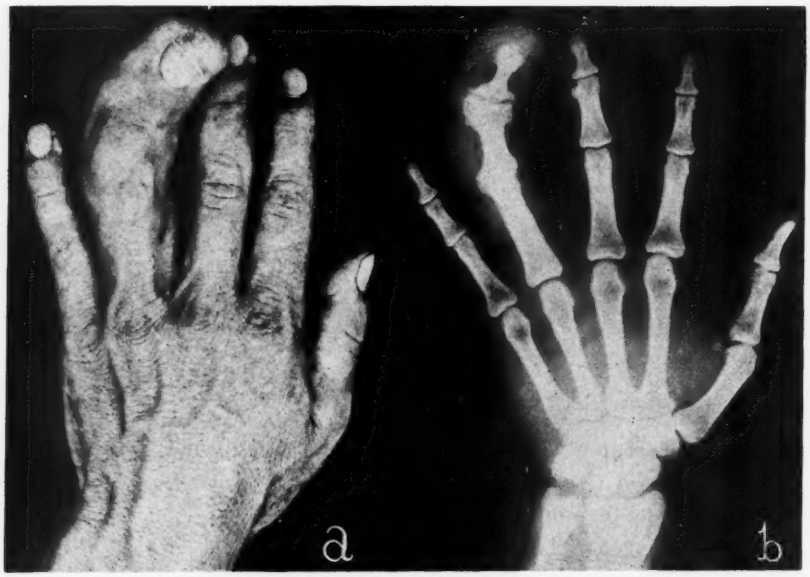

Fig. 6. *a*, dorsum of left hand, showing giantism of ring finger (megalodactylia). *b*, roentgenogram, showing enlarged phalanges with destructive arthritis of interphalangeal joints and small exostosis of middle phalanx of middle finger.

The primary step in management of any aneurysmal swelling depends on first establishing a diagnosis. In the involved extremity, usually the veins are engorged and the blood pressure is increased; moreover, the extremity usually is larger and warmer than the opposite one. Horton[9] has shown by arteriography that if the involved extremity is longer than the normal one the fistula usually is near an epiphysis. In some instances the bones may be involved. Bruits or thrills may or may not be present. While profound changes in the hydraulics and physiology of the vascular system are seen more often in association with the acquired forms of arteriovenous fistula, occasionally they are seen in the presence of congenital arteriovenous fistula. The diagnosis can be confirmed by determination of the oxygen saturation of the blood, as described by Brown, and by arteriography. In the past the treatment of congenital arteriovenous fistula has been unsuccessful. Lewis (1930) reported thirty cases, in twenty-seven of which the condition occurred in the extremities; of these twenty-seven patients, thirteen ultimately came to amputation.

We have found satisfactory the following technique for roentgenographic demonstration of arteriovenous communications in the hand. With the sphygmomanometer used as a tourniquet, 10 c.c. of a colloidal suspension of thorium dioxide (thorotrast) is injected into the brachial artery through a needle of small gauge. If serial roentgenograms are made immediately, often it is possible to demonstrate the flow of medium from arterial to venous tree through one fistula or more than one. This is of great importance to the surgeon, as it demonstrates the number, extent and situation of abnormal arteriovenous communications.

Cases have been reported by Horton and Ghormley and by Meyerding and Horton,[11] one of which is herein described again.

Fig. 7. Dorsal view of hands, showing discoloration and enlargement of right index finger.

Case IV. A man, aged 60 years, complained of pain and swelling of the right index finger of two years' duration. Eight months previous to his admission, the patient had sustained a right Colles' fracture; this had healed without untoward incident.

General physical examination revealed nothing of significance except for the findings relative to the right hand. (Figs. 7 and 8.) The blood pressure, in millimeters of mercury, was 170 systolic and 110 diastolic in the left arm. The right index finger was swollen as a result of the dilated veins. Early gangrene was noted at the tip of the finger. The maximal surface temperature of the right hand was 2.5° to 3°C. higher than that of the left hand. A clinical diagnosis of arteriovenous fistula was confirmed by the demonstration of a high admixture of arterial blood in the veins of the right hand. An abnormal communication between the artery and veins could be demonstrated in the arteriograms. Satisfactory recovery followed amputation of the index finger through the metacarpophalangeal joint. Dissection of this finger revealed at least three arteriovenous fistulas between one of the digital arteries and the accompanying vein. On the thirteenth postoperative day the concentration of oxygen in blood removed from the veins of the right and left hands was the same. In forty-nine days after the operation the systolic blood pressure in the right arm was 146 mm. of mercury and the diastolic pressure was 90; the systolic blood pressure was 155 in the left arm and the diastolic, 94.

Once the single or multiple character of an arteriovenous fistula has been established, the surgeon plans his approach to the lesion and ligates and divides, or excises, the communication. If the vessels are large, an insoluble ligature material, such as silk or linen, is best to use. The surgeon can be most certain of results when the artery and vein above and below the communication are divided and ligated and this is sometimes done when the collateral circulation has been well established or the lesion is of such extent that conservative management is impracticable.

In cases in which congenital arteriovenous fistulas consist of masses of vascular tissue, the excised tumors often are diagnosed as hemangiomas by the pathologist. Arteriovenous fistulas of this nature may respond favorably to injection of sclerosing agents into the blood spaces. However, the dilution factor in cases in which bruit is present may impair results. The extent of the injection should be under control and, following the injection, compression should

be applied, first manually and later by a sponge rubber bandage applied over the area. Treatment is best carried out under multiple injections.

Fig. 8. Arteriogram of right hand illustrated in Figure 7. Beginning gangrene. Arteriogram was made by injecting thorotrast (10 c.c.) into right brachial artery. Three arteriovenous fistulas were demonstrated in the amputated specimen.

TALIPOMANUS (CLUBHAND)

Normally the axis of the hand parallels that of the forearm. Disturbance in the relationship of these axes results in the deformity denoted "clubhand." It may be either congenital or acquired. Bony defects may or may not be present in cases of congenital clubhand. Cases in which the condition is contractural in origin and bony defects are absent, are very rare. Congenital clubhand is commonly associated with defects of one of the two bones of the forearm.

Bilateral clubhand is seen about as often as is the unilateral variety. Other congenital malformations frequently are associated with clubhand.

Clubhand Due to Absence of the Radius. This condition was observed by Tubby in eleven cases and he surmised that about three cases of this type were seen annually at the Royal Orthopaedic Hospital in London. In 1923, Kato analyzed 253 cases in a review of the literature. Radial defects are far more common than defects on the ulnar side of the forearm. Congenital absence of the radius frequently is associated with absent or rudimentary thumb and carpal bones on the radial side, atrophy of the forearm and an enlarged and curved ulna. Aplasia of the radius may involve the diaphysis only, the proximal end only, the distal end only, or the entire radius may be absent; the last is the most common malformation. The disorientation frequently involves vessels, nerves and muscles. A history of the same condition affecting forebears is noted only occasionally.

Clubhands usually are seen by the physician when the patient is in early life. This permits conservative measures such as massage, manipulation and immobilization to be carried out. Later in life reconstructive procedures may benefit function by correcting the deformity and securing stability.

Contracted muscles, scar tissue and tendons holding the hand in a deformed position can be corrected by plastic procedures. Stability can be secured by bone grafting, the bone being removed from the hypertrophied ulna or elsewhere. In 1928, Albee reported a case in which the result was excellent seven years following implantation of an autogenous graft. Osteotomy or excision of a wedge-shaped piece of bone may be necessary to overcome bowing of the ulna. An important part of the management of these cases is adequate immobilization with proper and persistent after care.

Clubhand Due to Absence of the Ulna. Clubhand due to congenital absence of any portion of the ulna is found much less frequently than clubhand resulting from absence of part or all of the radius. Kanavel was able to find in the literature reports of only about fifty cases in which the condition was attributable to absence of part of

the ulna. The clinical picture is characterized by a deformed elbow; a short, atrophic forearm; bowing of the radius; ulnar deflec-

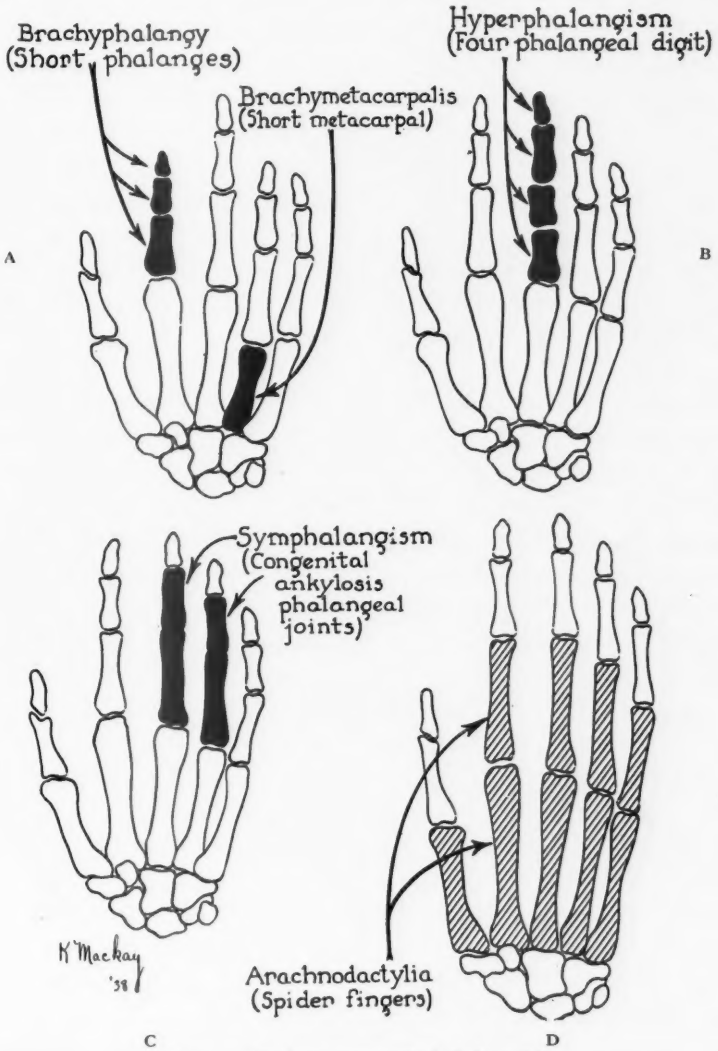

Fig. 9. Various congenital deformities.

tion of the hand and frequent suppression of the third, fourth and fifth fingers. Malformation of the carpal and metacarpal bones on the ulnar side of the hand is a commonly associated condition. The radius frequently is dislocated upward at the elbow. The function of the hand usually is much better than that of the hand which is associated with involvement of the radius.

Function in most instances is so satisfactory that surgical intervention is not indicated. When aplasia is present and is in such degree that bone grafting is required to secure stability, the hand usually is so badly suppressed developmentally that reconstructive surgical measures are useless.

Clubhand on a Contractural Basis. Clubhand on a contractural basis is analogous to congenital clubfoot. In the treatment of contracted clubhands, without bony defects, plastic procedures on the fascia and tendons usually are sufficient. These procedures are to be followed by adequate immobilization and proper physiotherapy.

MALFORMATIONS WITH EXTENSIVE MALDEVELOPMENT

Absence of segments of the humerus or forearm, with the hand attached to the body; absence of the forearm and hand; absence of the hand alone, and ectro-

dactylia or absence of fingers (which was discussed earlier) are among the more severe types of congenital impairment of growth. The extent of aplasia varies from absence of the smallest anatomic unit to absence of an entire extremity. Frequently more than one extremity is involved.

MALFORMATIONS WITH MILD MALDEVELOPMENT

Congenital Contraction Furrows. Congenital contraction rings, or so-called amniotic furrows, are deformities of milder degree. These contraction bands consist of dense fibrous tissue and may encircle the extremity at any level. They may be multiple and other congenital malformations may or may not be associated with them. That portion of the extremity which is distal to the contraction ring may exhibit any degree of maldevelopment and may determine the advisability of surgical removal of the contraction furrow.

Mention should be made of fusion of digits, of metacarpal bones and of carpal bones. Fusion of digits such as is seen in syndactylia already has been discussed. Fusion of the phalanges in the same finger will be discussed under symphalangism. Any degree of fusion of the metacarpal bones may be seen, varying from the slightest to the most complete. Partial fusion of the metacarpal bones usually takes place at their proximal ends.

CONGENITAL VARIATION IN THE CARPAL BONES

Supernumerary carpal bones are not uncommon. Numerous types of the condition have been described. In traumatic cases, frequently it is necessary to distinguish between fracture and a supernumerary bone. A roentgenogram of the opposite hand often will simplify a difficult diagnostic problem. The anomaly may be unilateral but in most cases it is symmetrical.

Many combinations of fused carpal bones have been described. The fusion may be either unilateral or bilateral. It may occur alone or in association with other congenital malformations. Fusion of the trapezoid and second metacarpal or of the trapezoid and os magnum may occur. The semilunar and cuneiform or semilunar and scaphoid also may be fused. The trapezium may be fused either with the first metacarpal or with the scaphoid. The semilunar also may be fused both with the unciform and the cuneiform. Complete lack of development of the carpal bones is more frequently encountered on the radial than on the ulnar side and usually is associated with malformation of the radius and thumb.

SYMPHALANGISM (CONGENITAL FUSION OF THE INTERPHALANGEAL JOINTS)

Symphalangism is an extremely rare hereditary anomaly characterized by fusion of the interphalangeal joints. (Fig. 9c.) Usually it is bilateral and frequently it is associated with other congenital malformations. Genealogic investigations have demonstrated that the anomaly is inherited according to Mendel's law. Drinkwater has traced the condition back fourteen generations. Should the function of the hand be seriously impaired the only applicable surgical procedure would be arthroplasty.

BRACHYPHALANGIA AND BRACHYDACTYLIA

Throughout the literature these terms are used synonymously to describe an hereditary deformity characterized clinically by shortening of the fingers or toes. (Fig. 9a.) Shortening of a finger, congenital in origin, may be due to complete lack of development of a phalanx (anphalangism), shortening of a phalanx (brachyphalangia) or shortening of a metacarpal bone. Stecher has suggested the term "brachymetacarpalia" to describe the deformity that is due to shortening of a metacarpal bone.

A congenitally short finger is more often associated with a short phalanx than with a short metacarpal bone. Brachyphalangia may affect any of the five digits; shortening of any of the five metacarpal bones may occur. Simple absence of a middle phalanx is most often seen. These malformations

usually are bilateral and are hereditary; surgical operation seldom is employed for their correction. Traction and oblique osteotomy or bone grafting are the only means of lengthening the finger.

HYPERPHALANGISM

Hyperphalangism is a very rare congenital malformation, characterized by the presence, in a finger, of four phalanges instead of three or, in the thumb, of three phalanges instead of two. (Fig. 9B.) Considerable controversy has arisen as to the origin of the supernumerary phalanges. Kanavel expressed the belief that supernumerary phalanges have their origin in disorientation of the epiphysis of the proximal phalanx. He offered the explanation that the protuberance seen on the radial side of the epiphysis may continue to grow and may become a separate phalanx. A familial history of the anomaly frequently is elicited. Lossen, in 1937, and Frere, in 1930, reported cases and furnished excellent roentgenographic illustrations.

ARACHNODACTYLIA (SPIDER FINGERS)

Arachnodactylia was first described by Marfan in 1896. It is characterized by the striking length of the extremities, especially of the hands and feet. (Fig. 9D.) To this are added other congenital malformations such as cardiac and pulmonary anomalies, ectopia lentis, hypotonicity of the muscles, spurs of the os calcis, and a highly arched palate. A roentgenogram of the hand discloses the presence of slender metacarpal bones and phalanges. The long bones of the extremities, the metacarpal bones and the proximal row of phalanges may be unusually long, while the middle and distal phalanges are of normal length.

MULTIPLE EXOSTOSIS

Multiple congenital osteochondromas, hereditary deforming chondrodysplasia (dyschondroplasia), hereditary multiple exostosis and diaphyseal aclasis belong in this group. Multiple exostosis is a hereditary condition characterized by more or less symmetrical bony or cartilaginous overgrowths occurring at the diaphyseal extremities. The hands may be involved as well as other parts of the skeletal system. Because of the proximity of the abnormal tissue to the epiphysis, disturbances of growth frequently are encountered. The cortex of the diaphysis may have irregular instead of regular margins. Of the bones of the hands, both phalanges and metacarpals may be involved but the carpus and epiphysis escape. (See Fig. 5C.)

CLEIDOCRANIAL DYSOSTOSIS

Cleidocranial dysostosis is congenital in origin and is characterized by absence of the clavicles, by cranial malformations and by disorders of dentition. The bones of the hands may be malformed. The distal phalanges are conical and may be shortened. The diaphyses of the proximal row of phalanges and metacarpal bones may be thinned and the cortices may be of increased density. There may be some shortening of the middle row of phalanges and of the metacarpal bones. The proximal row of phalanges may be expanded at their proximal ends. Klemmer, Snoke and Cooper, in 1931, and Pillsbury, in 1927, have reported cases with good illustrations and have described the roentgenologic appearance.

HEREDITARY DYSTROPHY OF THE NAILS

Various types of congenital malformation of the nails have been reported. The condition may or may not be associated with congenital malformations elsewhere in the body. Turner, in 1933, reported two families of which some members had dystrophy of the nails, associated with congenital anomalies of the joints; the condition affected thirty-five of seventy-nine persons. Sever, in 1938, reported a case in which the involvement was similar.

SUMMARY

It is obvious from the foregoing report that the multiplicity of congenital lesions presents problems in treatment which require accurate knowledge concerning

which of the bones and soft tissues are involved. By means of surgical treatment and postoperative physical therapy many of these deformities can be remedied, with benefit both in appearance and function.

REFERENCES

1. Albee, F. H. Formation of radius congenitally absent; condition seven years after implantation of bone graft. *Ann. Surg.*, 87: 105–110 (Jan.) 1928.
2. Bagg, H. J. Hereditary abnormalities of limbs, their origin and transmission. II. A morphological study with special reference to the etiology of club-feet, syndactylism, hypodactylism, and congenital amputation in the descendants of *x*-rayed mice. *Am. J. Anat.*, 43: 167–219 (Mar.) 1929.
3. Blair, V. P., and Brown, J. B. The use and uses of large split skin grafts of intermediate thickness. *Surg., Gynec. & Obst.*, 49: 82–97 (July) 1929.
4. Brown, G. E. Abnormal arteriovenous communication diagnosed from oxygen content of the blood of the regional veins. *Arch. Surg.*, 18: 807–810 (Mar.) 1929.
5. Callander, C. L. Study of arteriovenous fistula with an analysis of 447 cases. *Ann. Surg.*, 71: 428–459 (Apr.) 1920.
6. Drinkwater, H. Phalangeal anarthrosis (synostosis, ankylosis) transmitted through fourteen generations. *Proc. Roy. Soc. Med.*, 10: 60–68, 1916–1917.
7. Frere, J. M. A case having thumbs with three phalanges simulating fingers. *South. M. J.*, 23: 536–537 (June) 1930.
8. Horton, B. T. Hemihypertrophy of the extremities associated with congenital arteriovenous fistula. *Proc. Staff Meet., Mayo Clin.*, 6: 316–318 (May 27) 1931.
9. Horton, B. T. Some medical aspects of congenital arteriovenous fistula: report of thirty-eight cases. *Proc. Staff Meet., Mayo Clin.*, 9: 460–463 (Aug. 1) 1934.
10. Horton, B. T., and Ghormley, R. K. Congenital arteriovenous fistulas of extremities "visualized" by arteriography. *Surg., Gynec. & Obst.*, 60: 978–983 (May) 1935.
11. Horton, B. T., and Meyerding, H. W. Two traumatic arteriovenous fistulas involving the deep femoral artery and vein and the femoral artery and vein. *Proc. Staff Meet., Mayo Clin.*, 14: 4–7 (Jan. 4) 1939. (Read Sept., 1938.)
12. Hunter, William. Quoted by Veal, J. R., and McCord, Wm. Congenital abnormal arteriovenous anastomoses of the extremities with special reference to diagnosis by arteriography and by the oxygen saturation test. *Arch. Surg.*, 33: 848–866 (Nov.) 1936.
13. Kanavel, A. B. Congenital malformations of the hands. *Tr. Sect. Surg., Gen. & Abd., A. M. A.*, pp. 17–121 (June 8–12) 1931.
14. Kato, K. Congenital absence of the radius. *J. Bone & Joint Surg.*, 6: 589–626 (July) 1924.
15. Klemmer, R. N., Snoke, P. O., and Cooper, H. K. Cleidocranial dysostosis; report of a case. *Am. J. Roentgenol.*, 26: 710–715 (Nov.) 1931.
16. Lewis, D. Congenital arteriovenous fistulae. *Lancet*, 2: 621 (Sept. 20); 680–685 (Sept. 27) 1930.
17. Lossen, H. Hyperphalangie der Mittelfinger bei beidseitiger partieller Brachydaktylie (am I. bis III. Finger). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 56: 428–438 (Sept.) 1937.
18. Marfan, A. B. Quoted by Pino, R. H., Cooper, E. L., and Van Wien, Stefan. Arachnodactyly and status dysraphicus; a review. *Ann. Int. Med.*, 10: 1130–1143 (Feb.) 1937.
19. Pillsbury, H. C. Congenital absence of the clavicles (hereditary cleidocranial dystosis); report of case. *Am. J. Roentgenol.*, 18: 322–326 (Oct.) 1927.
20. Sever, J. W. Hereditary arthrodysplasia associated with dystrophy of the nails; report of a case. *New England J. Med.*, 219: 87–89 (July 21) 1938.
21. Stecher, W. R. Genealogical study of a case of symmetrical congenital brachydactylia. *M. Rec.*, 144: 5–8 (July 1) 1936.
22. Tubby, A. H. Deformities, Including Diseases of the Bones and Joints, 2nd ed. London, 1912. Macmillan.
23. Turner, J. W. An hereditary arthrodysplasia associated with hereditary dystrophy of the nails. *J. A. M. A.*, 100: 882–884 (Mar. 25) 1933.

RELEVANT ARTICLES NOT REFERRED TO IN THE TEXT

1. Albee, F. H. Orthopedic and Reconstruction Surgery, Industrial and Civilian. Philadelphia, 1919. W. B. Saunders and Company.
2. Andrews, G. C. Treatment of angioma: treatment based on ten years' experience at the Vanderbilt Clinic. *Arch. Dermat. & Syph.*, 37: 573–582 (Apr.) 1938.
3. Bircher, Eugen. Die Gabelhand, zugleich ein Beitrag zur Theorie der Missbildungen. *Beitr. z. klin. Chir.*, 111: 187–204, 1918.
4. Bloom, A. R. Hereditary multiple ankylosing arthropathy (congenital stiffness of the finger joints). *Radiology*, 29: 166–171 (Aug.) 1937.
5. Bloom, J. D. Macrodactylism. *New Orleans M. & S. J.*, 90: 29–30 (July) 1937.
6. Boorstein, S. W. Symmetrical congenital brachydactylia. *Surg., Gynec. & Obst.*, 43: 654–658 (Nov.) 1926.
7. Brailsford, J. F. The Radiology of Bones and Joints. Baltimore, 1934. William Wood.
8. Burrows, H. J. Developmental abbreviation of terminal phalanges. *Brit. J. Radiol.*, 11: 165–176 (Mar.) 1938.
9. Cockayne, E. A. An unusual form of brachyphalangy and syndactyly, with double proximal phalanx in the middle fingers. *J. Anat.*, 67: 165–167 (Oct.) 1932.
10. Cohn, Isidore. Normal Bones and Joints, Roentgenologically Considered. New York, 1924. Paul B. Hoeber.
11. David, V. C. Aneurysms of the hand. *Arch. Surg.*, 33: 267–275 (Aug.) 1936.
12. Ehrenfried, Albert. Hereditary deforming chondrodysplasia—multiple cartilaginous exostoses; a review of the American literature and report

of twelve cases. *J. A. M. A.*, 68: 502–508 (Feb. 17) 1917.

13. Gates, R. R. A form of brachyphalangy in a cousin marriage. *Lancet*, 1: 194 (Jan. 28) 1933.
14. Gill, A. B. Deformities of the hand. *New York State J. Med.*, 110: 1061–1063 (Dec. 27) 1919.
15. Greene, H. S. N. Hereditary brachydactylia and associated abnormalities in the rabbit. *Science*, n.s. 81: 405–407 (Apr. 26) 1935.
16. Holman, E. Recognition and treatment of arteriovenous communications. *Internat. Clin.*, 4: 154–167 (Dec.) 1934.
17. Horton, B. T., and Meyerding, H. W. A traumatic double arteriovenous fistula involving the profundis femoral artery and vein and the common femoral artery and vein. *Proc. Staff Meet., Mayo Clin.*, in press.
18. Jacobsen, A. W. Hereditary dystrophy of the hair and nails. *J. A. M. A.*, 90: 686–689 (Mar. 3) 1928.
19. Köhler, Alban. Röntgenology. New York, 1929. William Wood.
20. Lewin, P. Congenital absence or defects of bones of extremities. *Am. J. Roentgenol.*, 4: 431–448, 1917.
21. Manson, J. S. Hereditary syndactylism and polydactylism descriptive of recent additions to pedigree. *Brit. M. J.*, 2: 1044 (Dec. 8) 1934.
22. Marshall, Robert. Note on a family with brachydactyly. *Arch. Dis. Child.*, 4: 385–388, 1929.
23. Matheson, N. M. Some features of a case of multiple exostoses—diaphyseal aclasis (Keith). *Radiology*, 25: 631–632 (Nov.) 1935.
24. Meyerding, H. W. Exostosis. *Radiology*, 8: 282–288 (Apr.) 1927.
25. Musser, J. H. A note on symphalangism. *New Orleans M. & S. J.*, 83: 325–326 (Nov.) 1930.
26. Pemberton, J. deJ., and Saint, J. H. Congenital arteriovenous communications. *Surg., Gynec. & Obst.*, 46: 470–483 (Apr.) 1928.
27. Pendergast, Winifred. Inheritance of short, stubby hands. *J. Hered.*, 27: 448 (Nov.) 1936.
28. Perley, A. E. Two cases of brachydactylia. *Radiology*, 17: 1056–1058 (Nov.) 1931.
29. Peyton, W. T., and Leven, N. L. Hemangioma and its treatment. *Surgery*, 3: 702–718 (May) 1938.
30. Pino, R. H., Cooper, E. L., and Van Wien, Stefan. Arachnodactyly and status dysraphicus; a review. *Ann. Int. Med.*, 10: 1130–1143 (Feb.) 1937.
31. Reid, M. R. Studies on abnormal arteriovenous communications, acquired and congenital. I. Report of a series of cases. *Arch. Surg.*, 10: 601–638 (Mar.) 1925.
32. Reinhoff, W. F., Jr. Congenital arteriovenous fistula; an embryological study, with the report of a case. *Bull. Johns Hopkins Hosp.*, 35: 271–284, 1924.
33. Reynolds, L. R. Hyperphalangism accompanied by supernumerary epiphyses and muscular deficiencies. *Anat. Rec.*, 13: 113–126, 1917.
34. Seroiczkowski, A. Symmetrische Missbildung am beiden Händen und Füssen (Spaltbildung). *Ztschr. f. Anat. u. Entwcklngsgesch.*, 89: 145–155, 1929.
35. Steindler, A. Congenital malformations and deformities of the hand. *J. Orthop. Surg.*, 2: 639–668, 1920.
36. Steindler, Arthur. Reconstructive Surgery of the Upper Extremity. New York, 1923. D. Appleton and Company.
37. Stiles, K. A., and Weber, R. A. Pedigree of symphalangism. *J. Hered.*, 29: 199–202 (May) 1938.
38. Weingrow, S. M. Supernumerary distal phalanx of thumb; case report. *Am. J. Roentgenol.*, 23: 206–207 (Feb.) 1930.
39. Wilmoth, C. L. Hereditary joint abnormalities: case report. *South. M. J.*, 23: 1001–1002 (Nov.) 1930.
40. Yenikomshian, H. A., and Blake, H. K. Familial bony dystrophy with multiple exostoses. *Radiology*, 24: 623–625 (May) 1935.

THE MANAGEMENT OF POSTURAL DEFORMITIES OF THE LOWER EXTREMITIES

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WHEN any part of the lower extremity assumes abnormal posture, the rest of the leg is also affected.

For example, the lordotic lumbar spine and acutely tilted pelvis, by shifting forward the center of gravity, cause the femora to rotate internally; the knees may slacken (slightly flex) and increase their valgity; the feet assume a valgus and abducted position because the inwardly rotated leg has brought the weight-bearing line closer to the median sagittal plane. In this position ligaments are put on strain, and a greater amount of muscular energy is used to maintain the erect posture. Conversely, the flattened lumbar spine and more horizontal pelvis shift the center of gravity back and cause the legs to rotate externally. The second metatarsal then comes under the weight-bearing line, so that the body approaches a point of balance which can be maintained with minimum effort.

The part of the lower extremity showing the greatest deviation from normal is the foot. It is here that abnormalities are most important, because the foot is not only the base or pedestal upon which the superstructure is balanced; it is also a dynamic propulsive organ. Sir Arthur Keith[17] puts it in these words: "The foot is a postural structure; it cannot undergo any change of an advantageous kind unless every other structure in the body which is concerned in the maintenance of posture undergoes a harmonious alteration at the same time."

Since the foot plays such a vital part in leg posture, it is necessary to study its problems in detail. A brief anatomic survey is therefore desirable.

ANATOMY

The foot may be divided conveniently into three units: posterior (astragalus and os calcis); middle (five small tarsal bones which form a wedge, base medial); anterior (metatarsals and phalanges). The articulated foot forms a tripod of longitudinal springs (arches) upon which the leg is balanced. It is tied together by heavy ligaments and powerful muscles.

The conformation of the ankle, though a pure hinge-joint, provides against the slipping forward of the leg bones on the astragalus by the broadening of its body anteriorly.[14] This locks the two malleoli against the astragalus as they tend to slip forward because of body weight plus the active forward dislocating action of the long plantar muscles winding around behind their malleolar pulleys.

The frontal plane of the ankle joints is not at right angles to the sagittal plane, but oblique, and together the two ankles form an angle of 169 degrees open backward. Because of this obliquity the ankle joints tend in standing to bind on forward motion of the tibiae, and this propensity becomes an aid in keeping the upright position (Dane[10]).

The lateral ligaments of the ankle joint run down and backward from the malleoli to assist in counteracting the forward thrust of the leg on the astragalus. The superficial or calcaneotibial portion of the deltoid ligament passes from the malleolar tip to the sustentaculum tali, and so restrains the os calcis from too great eversion. The deep or fan-shaped deltoid part spreads out to attach to the whole medial surface of the astragalus and to blend with the spring ligament (calcaneoscaphoid) to form a suspensory mechanism for it.

In the astragalocalcanean or "sub" ankle joint is the key to most foot disorders. The astragalus rests in a cradle extending in an oblique sagittal plane

formed by the three facets of the calcaneus, the spring ligament, and scaphoid. These articulating surfaces are concave except for the posterior convex, saddle-shaped facet on the calcaneus. "The talus (astragalus) can slide like a bolt on its long axis which runs downward, forward, and medially."[14] It also allows for inversion and eversion of the os calcis, which rotates under it.

The transverse or mid-tarsal articulation (astragalo-scaphoid and calcaneo-cuboid) is complementary to the astragalo-calcanean. Therefore, these are joints of inversion and eversion. From the cuboid, a process projects backward (the calcanean angle) at its lower and medial border under the calcaneus.[14] It transmits the upward thrust of the peroneus longus to the calcaneus. Considerable variation in this joint up to the purely vertical is noted by Dane.[9]

The course and insertion of the *long* plantar muscles, the posterior tibial, flexor hallucis longus, and peroneal longus, require particular mention: As the posterior tibial tendon curves under its pulley, the medial malleolus, it can exert a strong forward and lifting action, approximating the medial malleolus to the scaphoid tuberosity. It runs forward under and superficially to the spring ligament, giving it support, and inserts two-thirds into the tuberosity of the scaphoid and one-third into finger-like bands diverging to the remainder of the tarsus (except the internal cuneiform), and to the second, third, and fourth metatarsal bases. The flexor hallucis longus is the only tendon running directly under the sustentaculum; it gives a strong upward and outward thrust on this pulley. The peroneus longus uses the external malleolus as a pulley to wind forward under the cuboid, and takes its way diagonally under the sole of the foot to the base of the first metatarsal and first cuneiform.

The abductor hallucis is an important *short* plantar muscle because although it has lost its active abduction power, it depresses the head of the first metatarsal and acts as a spring tie-rod along the inner border of the foot.

DYNAMICS OF THE FOOT

In recent decades more attention has been paid to the dynamics of the foot than to its static architectural arch structure. The tendency is to avoid the idea of the arch with its keystone. Some writers deny their existence, and regard the hollowed sole of the foot as made up of flexible trusses or springs.

Speaking of the foot, Sir Arthur Keith[17] says, "Attention must first be directed to its prime movers, its muscles—Nature never uses ligaments as prime supporters in the structure of the animal body . . . ligaments serve only as safeguards." Steindler[25] agrees that "in the maintenance of the normal configuration of the foot the muscles stand in the first line of defense."

Dudley Morton,[21] Lake,[19] and Wiles,[27] however, believe that the muscles merely assist in maintaining balance, and that weight is distributed throughout the foot from bone to bone much as it is transmitted from femur to tibia. Wiles concedes that the intrinsic muscles may play a part as tie-rods to the long arch. He emphasizes the independent up-and-down action of the hallux unit, which includes the inner cuneiform, and assigns to the abductor hallucis and the peroneus longus the function of depressing this metatarsal head. There is no doubt that this motion was well-developed in the grasping function of the hallux unit in the arboreal stages of foot evolution.

Nevertheless, it is clear that muscle pull can profoundly change the balance of the foot. This can well be seen in the deformities resulting from muscle imbalance in anterior poliomyelitis.

The three long plantar muscles play the major rôle in maintaining foot equilibrium. Just as the posterior tibial is the strongest, most persistent offender in producing varus deformity in anterior poliomyelitis, so it is the chief defender against eversion of the foot in walking or standing. The peroneus longus is generally considered the second most important muscle in its sling-like supportive action, as it passes under the

tarsus, tying it together, and secondarily stabilizing the hallux. In this latter capacity it is really a synergist to the tibialis

Fig. 1. Foot of seven months fetus, before the fatty instep pad found at birth has developed. A well-marked arch is already present. (From Lake's "The Foot," William Wood.)

posticus. By some authors, the flexor hallucis longus is given first place because it is a large, bulky muscle and because it acts directly on the os calcis through the sustentaculum.

BONY ABNORMALITIES OF THE FOOT INFLUENCING POSTURE

That hypermobility and shortness of the first metatarsal may influence foot balance and have to be compensated for, is shown by Morton.[21] Variation in ossification and accessory or inconstant bones may also be of importance in production of the everted foot and may present a bony resistance to correction. Pfitzner states that synostosis of constant tarsal elements takes place through the medium of an inconstant one. Dane[9] in a careful study of 177 specimens found an articulation between scaphoid and cuboid in 43 per cent; astragalar-cuboid 5 per cent (which must have an effect on foot mechanics); and calcaneo-scaphoid articulation in 28 per cent, with fibrous ankylosis in one and a bony bridge ⅜ inch thick in two. This was described in later years by Slomann as coalitio calcaneonavicularis. Complete union is by fusion of the inconstant bone (os calcaneous secundarius) to its two tarsal neighbors. This fixes the foot in an everted position.

Kidner[18] has emphasized the abnormal attachment of the posterior tibial tendon in cases with an accessory scaphoid. Its attachment is more inward and upward on the scaphoid, and may occur even without the presence of the inconstant extra bone. Such an attachment lessens its supinating power.

POSTURAL DEFORMITIES OF THE FOOT

The term "flat" foot has been loosely used for pronated, weak, or splay foot. In discussing this syndrome of faulty weight-bearing, Jones and Lovett[16] prefer to use the more definitive word "strain." The true flat foot, that is, absence of concavity of the inner border of the foot, is infrequent except in certain Negro types, and is not ordinarily subject to strain. The usual apparent obliteration of this concavity is due to eversion. In disturbed postural balance the concave inner border is restored in the flexible foot as soon as it is brought under the leg to its normal position in balanced weight-bearing. Even the infant's foot is not flat, as shown by Dane, Lake, and others. (Fig. 1.) The inner longitudinal curve of the foot is, except in thin babies, masked by a pad of fat which, according to Dane,[11] protects the architecture of the foot until it becomes strong enough to dispense with this support.

The superincumbent body weight reaches the foot through tibia and astragalus and is distributed to fore and hind foot in a ratio of three to five. The medial eccentric position of the astragalus in the tarsus and the pronating and supinating movement in the "sub" ankle joint (subastragalar and mid-tarsal) allow this weight to be thrown easily to the inner side of the foot unless the latter is kept in balance by its muscular stabilizers, the long plantar muscles. This elastic inner side of the foot, which has sacrificed stability for the mobility productive of an effortless, springy gait, is the area most vulnerable to abnormal strains.

In young children the pronated foot causes no symptoms beyond a slight awkwardness of gait. If medical advice is sought, it is only because of an apparent enlargement of the inner aspect of the ankle. In the adult, symptoms of foot strain appear after decompensation of muscle control because of: increased weight; weakened muscles following illness; overuse (change of occupation) with feet in a position of imbalance; or continued use of faulty shoes. As one author aptly says, "The foot is the first structure to express by pain the generally relaxed fatigued condition."

Symptoms may come on with dramatic suddenness in a foot that, just struggling along, is forced to take on new and heavier burdens such as standing all day or nursing duty. Much time and suffering can be saved by careful inspection of newcomers to such kinds of work. Osgood[23] found it of definite value to measure by spring balance the relative strengths of supinator and pronator muscles. Normally the ratio is five to four in favor of the supinators. Incoming student nurses were so tested, and exercises, heel wedges, and so forth were given prophylactically to those who fell below normal. As a result, the incidence of foot strain dropped noticeably in classes so supervised.

Symptoms range from slight tenderness over the ligamentous attachments and a dull ache or tired feeling, to acute pain in the entire foot with swelling and extreme tenderness. Freiberg[12] used the tenderness demonstrable over the sustentaculum as the first sign of incipient foot strain, even before subjective symptoms were noticeable. A slip of the deltoid ligament which attaches to it is the first part to feel the effect of strain from an everted foot. In long-standing cases of abnormal weight-bearing, heavy calluses appear on the plantar surface of the foot in areas subject to increased pressure, especially under the inner aspect of the heel or great-toe joint.

Diagnosis. It may be thought that static error can be detected at a glance, but this is only partly true. The everted heel with its abducted forefoot can be seen, but most organic disturbances of the foot also have some complicating static deviation which is visible. The difficulty lies in identifying the organic condition underlying the apparently simple postural defect. Lack of attention to the possibility of organic disease naturally leads to disappointment in treatment.

Peripheral vascular disease is to be suspected in cold, cyanotic feet, particularly if accompanied by a history of cramping in calf muscles. Blanching of the soles when raised above heart level is a strong indication of its presence.

The subacute or chronic case of gout has more than once been "treated" by arch supports, but the intermittent character of the symptoms, *x*-ray changes, and finally uric acid determination, should identify this not-so-infrequent disturbance beyond the possibility of such error.

In their incipient stages, central nervous system diseases that lead to foot abnormalities may also cause confusion. Tests for reflexes, including the plantar response, should always be made.

Mild arthritis too may be overlooked unless attention is paid to history, other joints, and *x*-ray examination. Moreover, disturbances of alignment of the lower extremity, coxa vara, genu valgum, and inequality of leg length must be taken into account.

Treatment. Fundamentally, the aim of treatment is to restore correct weight-bearing alignment of the foot with the leg to assure transmission of weight both in standing and in motion so that the tripod-like weight distribution in the foot receives its proper proportion at each of the three main supporting points.

For young children, who are usually symptom-free, Whitman[26] is insistent on corrective treatment. He says, "It is in childhood that the prevention of subsequent weakness and deformity is of the first importance." To the child too young to coöperate in corrective exercises, his

rocker-type arch support is of distinct value.

It is different with those adults, particu-

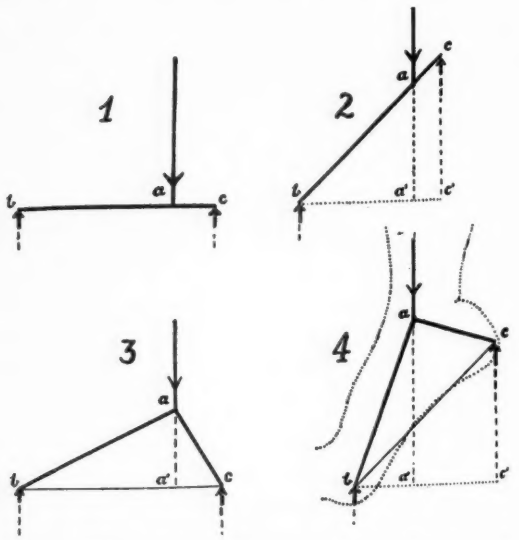

Fig. 2. Diagrams to illustrate the mechanics of the high heel. If the foot were a simple lever (1) its elevation would produce no change in the proportion of the weight falling on *b* and *c*, for (2) *ba* and *ba'* diminish in the same degree as *ac* and *a'c'*. The actual arrangement is, however, seen in (3), where the relative lengths were obtained from roentgenograms. The axis of rotation is at *a* some 2 inches above the sole, and when the heel is raised the result is seen in (4), where *ba'* is tremendously diminished while *a'c'* is increased, so that a much greater proportion of the weight is now carried at *b*. (From Lake's "The Foot," William Wood.)

larly elderly folk, whose poorly balanced feet may be painless and have become adjusted to the changed forces of weight-bearing. In such cases it is wise to curb one's enthusiasm for postural correction, which may only precipitate trouble. Slight symptoms in such patients are best alleviated by a mild supportive foot plate or pads.

In the extreme, acute case, bed rest is indicated, followed by inversion strapping or even plaster boot. When symptoms have subsided, the patient may be handled as is the ordinary protracted case, described below.

The chronic patient intelligent enough to be coöperative and old enough to understand (this includes some children as young as 6 or even 4) should bend every effort toward correction by exercise. Arch supports should be avoided whenever possible, but if used, should be looked upon as crutches only. The patient must be impressed with their weakening effect on the foot musculature. All too often a vicious circle is set up: the patient obtains relief from pain by use of a support; he relies on it exclusively, makes no effort to restore muscle tone; and as the result of the increasing weakness in foot musculature, he becomes more and more dependent on the artificial aid. As the years go on, it has to be made more supportive, until wearing it becomes a burden, and all semblance to ordinary elastic gait disappears.

As a matter of fact, carefully selected shoes may provide the only needed artificial support.

The medical profession has long been aware of the influence of foot-gear on foot mechanics. M. Andry in his *Treatise Orthopaedia*,[13] 1742, wrote, "Shoes that are too high-heeled will make the bodies of children crooked." Peter Camper's *Dissertation on Best Form of Shoes*, 1791, influenced thought on footwear for generations, and T. S. Ellis in 1889 said, "Let the form of the boot lasts correspond in shape to that of the feet in action."[2]

This ideal has been arrived at to a degree in the present type of semi-orthopedic shoe, which by merely eliminating the pointed end gives adequate toe-room, and is at the same time pleasing in appearance. The full orthopedic shoe with its exaggerated in-swing of the sole does little more than produce corns and other pressure manifestations. One author thinks they would be helpful only to the palm-climbing native who uses his feet in an oversupinated position! In short, they are ugly, unnecessary, and not tolerated by the intelligent patient except under duress.

In the proper shoe, a straight inner border is desirable. The heel should be snug (combination width lasts provide the means) and the waist of the shoe should clasp the instep firmly. There should be ample toe-room. The semi-orthopedic shoe

generally has a semi-rigid shank, which is advantageous because it will not lose shape easily, thereby prolonging the corrective effect of heel wedges and so forth. One of the objections which often arise in otherwise satisfactory shoes is that the heel-to-ball length is shorter than that of the foot, so that the arch of the shoe in its forward part falls short of that of the foot. This has the effect, if the upper is snug, of strapping the foot firmly to a board and greatly limiting any up-and-down play of the independent first metatarsal unit. Shoe manufacturers manage to accomplish this result in another way also, by flattening the vamp part of the upper in order to eliminate wrinkles. This again ties down the first metatarsal.

Little need be said about the woman's high-heeled shoe. A brief study of the diagrams reproduced from Lake's book,[19] *The Foot*, is convincing. (Fig. 2). Even the 2½ inch heel causes the metatarsals to meet the ground at an angle of over 50 degrees. An average foot in good postural tone, however, can tolerate them for three or four hours without discomfort. Young women may insist that they suffer no ill effects from continually wearing them, but the throngs of older women besieging orthopedic clinics and supporting appliance makers belie their statement.

Alteration of shoe balance was bequeathed to us by H. O. Thomas, who described his crooked heel in 1874. Originally this wedge was carried forward to end just behind the first metatarsal head, giving the foot a correction similar to that attributed to the Whitman foot plate. The present-day Thomas or extension heel, however, is carried forward only ½ or ¾ inch under the inner border of the arch. It should come forward to the plane of the tuberosity of the scaphoid, which is rarely less than ¾ and often 1 inch. The wedging of the inner border of the heel may be 3/16 to ¼ inch. Usually it is effective in correcting the heel eversion if the heel of the shoe fits snugly and has a firm counter. J. J. Nutt[22] has further modified the original Thomas heel by using a short anterior heel just behind the first metatarsal head. It is built to balance the sole,

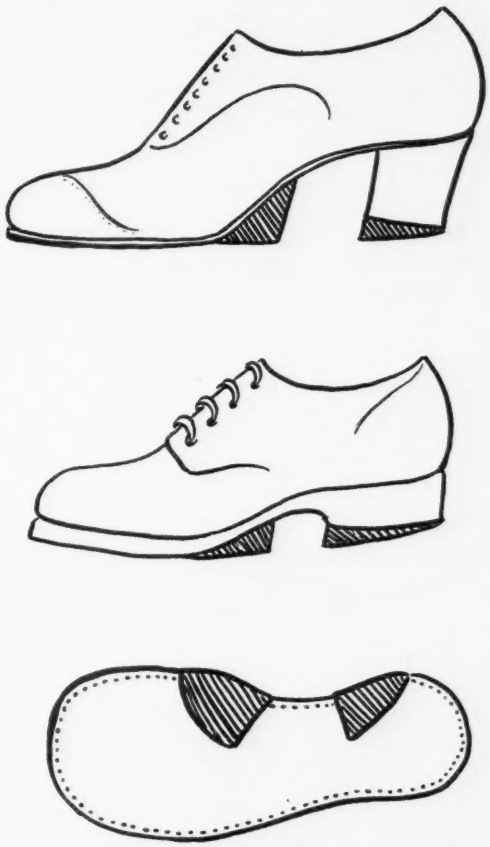

Fig. 3. Anterior heel. (From Nutt, in *Am. J. Surg.*, 32: 53, 1936.)

level with the regular heel, which has had its forward inner corner raised ⅛ to ¼ inch for correction of heel eversion. (Fig. 3.) This anterior heel effectively checks abduction of the forefoot and yet permits some flexibility to remain in the shoe. (Rigid metal arch supports do not.)

If actual support under the scaphoid is needed for a time completely to relieve symptoms, the rubber oval scaphoid pad may be cemented into the shoe. If placed far enough back toward the heel, it does not interfere with the action of the first hallux unit, and in addition to its supporting and supinator action, it effectively limits forward slipping of the very flexible foot.

For localized pressure points under metatarsal heads, the conventional meta-

tarsal pad cemented into the shoe suffices. Even better is the leather metatarsal bar placed on the sole just behind the metatarsal heads. If the forefoot is of the very flexible accordion type, it is better to incorporate the metatarsal rubber pad (felt pads mat down) in a leather metatarsal cuff, which keeps the forefoot from unduly splaying out. (Fig. 4.)

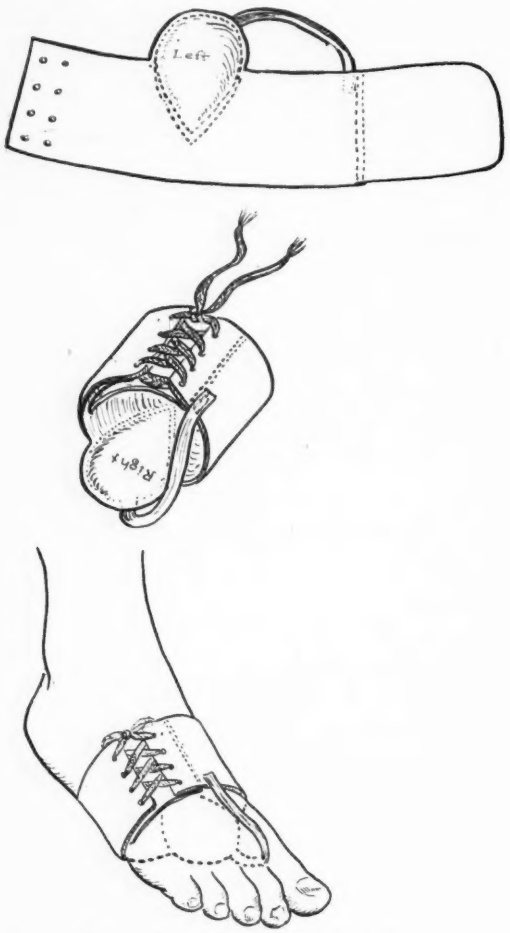

Fig. 4. Leather metatarsal cuff.

Exercise, the most important step in conservative treatment of postural deformities of the foot, is, ironically, the most difficult, because it is not easy to get and keep the patient's coöperation. Handing him a printed explanation of exercises is wasting paper; he must be not only convinced of their value but also made enthusiastic about persevering at them.

The chief disadvantage of exercises and exercising devices is that a certain hour must be set aside for them, usually in the evening. There is much doubt in my mind that ten minutes of even conscientious exercise at the end of a fatiguing day can counteract the breaking down effect of eight hours or more of pounding hard, unyielding city pavements or floors. Therefore, I depend upon one exercise which can be done in the shoes six or eight times daily, never for more than sixty seconds at a time, and at odd moments such as while shaving, brushing the teeth, or standing in subways. Its main value is that it can be repeated frequently and without loss of time. One merely has to think of it to do it. The exercise consists of standing in a slightly forward-leaning position to increase the weight on the forefoot. The toes are firmly plantar-flexed, pushing up the mid-foot like a cat's arched back, and rolling the foot slightly to its outer border. All this must be done with real effort, as if actually lifting the body weight. The tendency for the head of the first metatarsal to leave the ground must be firmly resisted. This exertion calls into action the peroneus longus. The contraction of the toes employs the long and short toe-flexors, and the moderate inversion motion makes the tibialis posticus work. Contracting the gluteii maximii (pulling the cheeks of the buttocks together) while thus curling the toes tends to correct the internal rotation of the leg which accompanies foot pronation, and it helps to bring the leg and foot into equilibrium more quickly. The value of this exercise (gluteal contraction) was emphasized by Lowman in 1912, has been reiterated from time to time by subsequent authors, and has been periodically forgotten by the majority.

If heel cords are short, that is, if they do not permit dorsiflexion of the supinated foot to a right angle, they should and can be stretched. This can be done manually or by the following method. The patient faces the wall an arm's length away, standing on the outside of his feet without shoes—toes curled under, heels on the floor. Keeping the body stiff, he lets it fall toward the

wall by bending the elbows. The feet must be kept supinated in order to avoid straining the inner borders. (Fig. 5.) If this performance is properly done, real strain is felt behind the knees and in the calves. Some authors deny that the tendo Achillis can be stretched. Thoroughness and perseverance in the fashion here recommended will prove them wrong. The rare case, so severe and persistent that stretching will not cure it, can be so much helped by lengthening that operative correction is worthwhile.

The Shaffer shoe and its modifications are positive mechanical means of stretching heel cords.

To obviate aching in the calf, an active symptom of short tendo Achillis, some men advocate raising the heel. To my mind this is robbing Peter to pay Paul, because although it may relieve the symptoms, it throws extra weight on the metatarsal heads and hastens the day when they will sing out with pain.

One other common exercise is to be mentioned only to be condemned: rising up on the toes, tilting to the outer border of the feet, and lowering the heels to the ground. The upward and downward motion of the heels is done by the calf group, usually already shortened and hypertrophied. The outward rolling calls only the peronei into action to combat the tendency of the feet to collapse laterally to an advanced degree because of the oblique set of metatarsal heads. The tibials and toe flexors may be completely passive.

For the older patient who cannot benefit by exercise, and for the uncoöperative patient who will not, artificial aids may be employed. Metal arch supports are better avoided unless the deviation is extreme or overweight is marked. Wedged heels and rubber scaphoid pads usually suffice. The single outside bar brace with inside T strap can be used to advantage in the very flaccid foot to hold correction until training can restore the muscles to somewhere near the normal. It is of particular value in the convalescent treatment of peroneal spasm.

Almost as efficient corrective support can be obtained temporarily by an inversion adhesive strapping. It is not enough, however, to strap the hind foot in inversion because then the long lever of the forefoot is not controlled and forces the heel back to its original position, stretching the adhesive. The forefoot should be held in adduction, and overlapping diagonal strips of the tape should be carried from just behind the head of the fifth metatarsal up on to the inner aspect of the leg, there to be incorporated into the posterior stirrup strapping. (Fig. 6.)

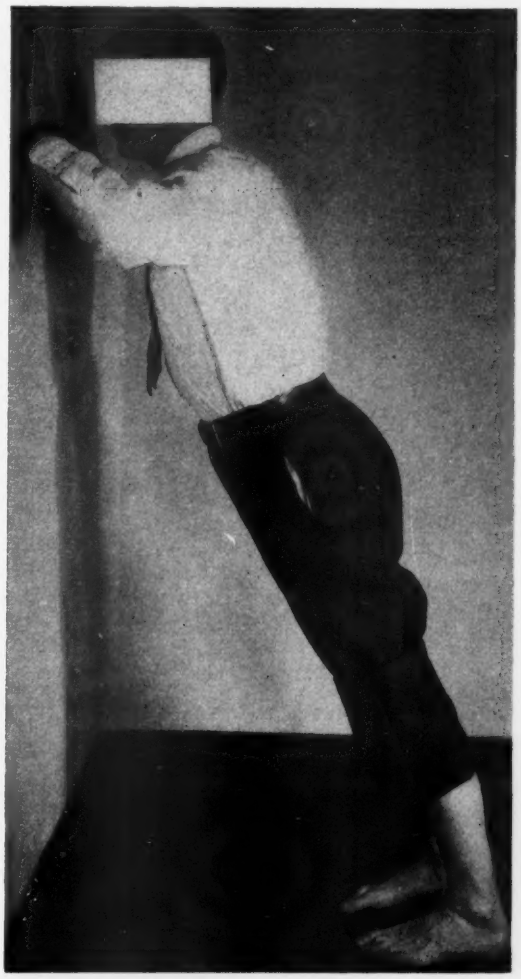

Fig. 5. Exercise for stretching of tendo Achillis.

In the more extreme degrees of flexible pronated foot, it may be necessary to resort to operative correction if any semblance of foot balance is to be achieved. Of the many operations

tried and advocated, three deserve particular consideration:

Scaphocuneiform fusion with remodel-

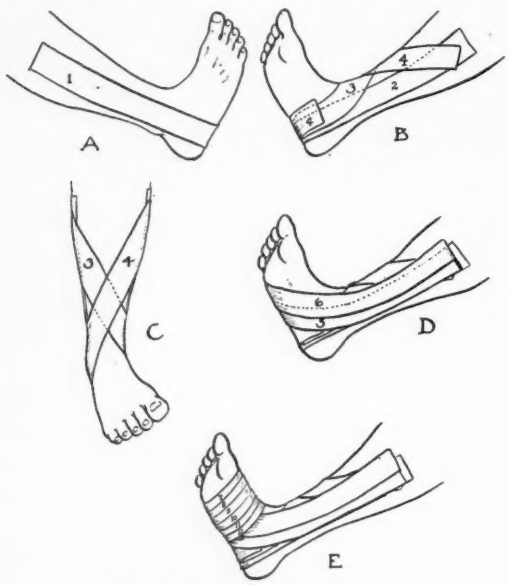

Fig. 6. Inversion foot strapping.

ling of the inner border of the foot was described by Hoke[15] in 1931. It has given excellent results in his and others' hands. Hoke's own cases were presented after a five- and six-year follow-up. Attention must be paid to proper moulding of the foot with adequate plantar flexion of the first metatarsal head.

For anomalous attachments of the tibialis posticus usually associated with an accessory scaphoid, Kidner,[18] in 1933, reported a transplantation. The posterior tibial tendon was returned to its normal site in a groove under the scaphoid. When done in the properly chosen foot and followed up by an adequate muscle training, this operation gives very satisfactory results.

Oscar Miller,[20] in 1927, gave an account of advancement of the calcaneoscaphoid (spring) ligament by means of an osteoperiosteal flap. This changes the contour of the inner border of the foot, but does not cause ankylosis of any of the tarsal joints.

POSTURAL DEFORMITIES OF THE LEG

Practically all deformities of the leg are caused by organic changes in its bone or soft tissue structure. However, Kuhns attributes the very common knock-knee deformity seen in adolescents, particularly girls, to poor posture resulting from a general muscular imbalance. The prominent lax abdomen allows forward inclination of the pelvis with relaxation of the glutei and consequent inward rotation of the femora. This produces an apparent and later real external rotation of the tibiae. Such a stance habitus if long continued, influences the growing long bones until an organic knock-knee gradually ensues. In examining a thousand girls from 8 to 18 years of age, Kuhns found knock-knee on such a basis in 20 per cent. He measured the distance between the malleoli with the patient supine, legs straight, and knees touching. One inch separation or less was considered normal, between 2 and 3 inches moderate, and 4 inches or more severe.

As regards treatment, Kuhns feels that practically all mild and moderate knock-knees can be corrected with wedges (up to ¼ inch) on the inner border of the shoes, supplemented with exercises to improve the strength of the inner hamstrings. Knee flexion and extension exercises help if a pillow is inserted between the knees and the feet are tied together. Cyriax[8] also stresses muscle re-education in those who show muscle imbalance.

This malalignment of the knee, being confined primarily to a definite age group, is of slight importance compared with the postural deformity of the foot, which, occurring continually throughout all age groups and frequently to a severe degree, is much more serious. It is for this reason that the latter must form the basis of any discussion of postural deformity of the lower extremity.

SUMMARY

That postural deformity in the foot influences general body mechanics has been emphasized here. That defective body posture also affects foot mechanics must also be remembered.

The discussion of anatomy and function of the foot supports belief in the fundamental importance of an adequate muscle tone and balance.

Under diagnosis, the possibility of confusion of postural difficulties with organic disturbances is mentioned.

The several methods of conservative treatment are touched upon, and the matter of exercise is elaborated.

Restoration of muscle tone and of postural balance is considered fundamental.

REFERENCES

1. Badgley, Carl E. Coalition of the calcaneus and navicular. *Arch. Surg.*, 15: 75–88 (July) 1927.
2. Bick, Edgar M. Source Book of Orthopaedics. Baltimore, 1937. Williams & Wilkins Co.
3. Brown, Lloyd T. A consideration of extrinsic and intrinsic muscles of the foot. *Am. J. Orthop. Surg.*, 10: 18–29 (Aug.) 1912.
4. Brown, L. T. The occurrence of weak feet and foot strain in school children and methods of examination. *Tr. 4th Int. Congress on School Hygiene*, 1913.
5. Cotton, Frederic J. Flat foot and other static foot troubles. *Boston M. & S. J.*, 182: 1–11 (Jan. 1), 1920.
6. Cotton, F. J. Foot statics and surgery. *New England J. Med.*, 214: 353–362 (Feb. 20) 1936.
7. Crego, C. K., and McCarroll, H. R. Recurrent deformities in stabilized paralytic feet. *J. Bone & Joint Surg.*, 20: 609 (July) 1938.
8. Cyriax, E. Common postural deformities and their treatment by exercises. *Brit. J. Physiol. Med.*, 1: 161–165 (May) 1938.
9. Dane, John. A study of some of the bones and joints of the foot. *Tr. Am. Orthop. A.*, xiii, 159, 1900.
10. Dane, J. Some effects upon the leg of pronation of the foot. *Tr. Am. Orthop. A.*, x, 40, 1897.
11. Dane, J. Further studies upon the arch of the foot in infancy and childhood. *Tr. Am. Orthop. A.*, xi, 54, 1898.
12. Freiberg, Albert H. Objective symptomatology of foot strain. *J. A. M. A.*, 75: 466–468 (Aug. 14) 1920.
13. Goldthwait, Joel E. Backgrounds and foregrounds of orthopaedics. *J. Bone & Joint Surg.*, 15: 279, 1933.
14. Grant, J. C., and Boileau, A. Method of Anatomy. Baltimore, 1937. William Wood & Co.
15. Hoke, Michael. An operation for the correction of extremely relaxed flat feet. *J. Bone & Joint Surg.*, 13: 773, 1931.
16. Jones, Robert, and Lovett, Robert W. Orthopedic Surgery. N. Y., 1923. William Wood & Co.
17. Keith, Arthur. History of the human foot and its bearing on orthopedic practise. *J. Bone & Joint Surg.*, 2: 10–31, 1929.
18. Kidner, F. C. The prehallux in relation to flat foot. *J. A. M. A.*, 101: 1539–1541 (Nov. 11) 1933.
19. Lake, Norman C. The Foot, 2nd Ed. Baltimore, 1938. William Wood & Co.
20. Miller, Oscar L. A plastic flat foot operation. *J. Bone & Joint Surg.*, 9: 84–91, 1927.
21. Morton, Dudley J. The Human Foot. New York, 1935. Columbia University Press.
22. Nutt, John J. Function of medio-tarsal joint. *Am. J. Surg.*, 32: 53–55 (April) 1936.
23. Osgood, Robert B., and Allison, Nathaniel. Fundamentals of Orthopaedic Surgery in General Medicine and Surgery. New York, 1931. Macmillan Co.
24. Schwartz, R. Plato, Heath, Arthur L., Brownell, Chas. G., and Power, Walter C. Useful methods of examination as related to cause and treatment of painful feet. *Physiotherapy Rev.*, 19: 19–24 (Jan.-Feb.) 1939.
25. Steindler, Arthur. The mechanics of Normal and Pathological Locomotion in Man. Springfield, Illinois, 1935. Chas. C. Thomas.
26. Whitman, Royal. The importance of positive support in the curative treatment of weak feet. *Am. J. Orthop. Surg.*, 11: 215 (Oct.) 1913.
27. Wiles, Philip. Flat feet. *Lancet*, 1: 5803 (Nov. 17) 1934.
28. Willis, T. A. Function of the long plantar muscles. *Surg., Gynec. & Obst.*, 60: 150, 1935.

STABILIZATION OF THE HIP JOINT

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STABILIZATION of an unstable hip joint is probably more essential to efficient ambulation than analogous measures in any other joint in the body. In the absence of gross deformity, function can be restored to the flail knee and ankle by means of properly constructed apparatus. The mechanics of the hip in weight bearing are such that efficient apparatus cannot be adjusted to compensate adequately for instability. Consequently partial or complete restoration of function can be accomplished only by reconstructive surgery.

In surgical stabilization, as in all surgery of the hip, due consideration must be given the mechanical and physiologic principles involved. These may be briefly enumerated as follows: (1) anatomy and mechanics; (2) embryology and evolution; (3) osseous structure; and (4) circulation.

Anatomy and Mechanics. In weight bearing the normal relation between the femur and pelvis is maintained by osseous, ligamentous and muscular supports. When any of these supporting structures are impaired, the pelvis cannot be fixed and instability results. This status is elicited by the classical Trendelenburg sign.

Embryology and Evolution. The femur and innominate bone are differentiated from the primitive skeletal anlage at the 0.5 cm. stage, about the fourth or fifth week of gestation. The acetabulum is formed by the simultaneous development of three separate bones. Failure of these three bones to develop synchronously results in a defective support for the femur in weight bearing. Epiphyseal defects are well illustrated by congenital dislocation of the hip and allied conditions.

In the early embryo there is no femoral neck, the head being supported on the upper extremity of the femoral shaft. At birth the neck is indicated by an angle of about 150 to 160 degrees. As growth increases, this angle decreases, so that when adult age is reached the normal angle between the femoral shaft and neck varies from 125 to 130 degrees. After middle age the angle further decreases as a result of structural changes of advancing age.

Osseous Structure. Normally the weight of the trunk is transmitted from the pelvis to the femoral neck on an oblique axis. The stress and pressure of weight bearing and growth are responsible for the development of several systems of bony trabeculae in the femoral neck. The arrangement of these trabeculae, and indeed, the conformity of the entire femur, are ideally suited for the transmission of weight from the pelvis to the knee joint. Physiologic decalcification of this osseous structure may be produced by the inactivity of old age, or by prolonged immobilization.

Circulation. The principal blood supply to the head and neck of the femur is derived from the capsular branch of the lateral circumflex artery and from the ligamentum teres. When anatomic reconstruction of the hip joint is desired, the preservation of the capsular artery is of paramount importance; however, surgical stabilization of the hip joint is often necessary after severance of these vessels.

Etiology. The causes of instability of the hip joint for which operative measures are required may be enumerated as follows: (1) ununited fractures of the neck of the femur; (2) dissolution of the head and neck of the femur as a result of pathologic processes; (3) congenital dislocation of the hip joint; (4) traumatic dislocation of the hip joint; (5) paralytic dislocation of the hip joint; and (6) Charcot joint.

While all of these conditions are characterized by an imbalance between the femur and pelvis, the choice of operative procedure varies with several factors. The status of the femoral head and neck, the integrity of the soft tissues acting on the joint, and the age and general condition of the patient must be carefully considered.

Fig. 1. Age 46, eighteen years following bone graft for non-union of thirty months' duration.

Fig. 2. Age 49 years. Whitman reconstruction operation. Excellent function.

Surgical Approach. In all operations upon the hip joint the anterior iliofemoral approach, popularized by Smith-Petersen, is the approach of choice. When both the trochanter and hip joint must be exposed, the approach described by Dupuy de Frenelle, or the incision recently popularized by Watson-Jones, is employed by the author.

The technique described by Dupuy de Frenelle is as follows: The skin incision is U-shaped, passing along the iliac crest as far as the anterior superior spine, then curves backward below the greater trochanter. The tensor fasciae femoris is severed at its origin and the sartorius retracted. The gluteal muscles are stripped from their insertion, exposing the hip joint.

In the Watson-Jones approach, the skin incision begins 1 inch below and anterior to the anterior superior spine and passes directly to the trochanter, where it turns down along the lateral surface of the thigh. Dissection is carried out through the interval between the tensor fasciae and the gluteus medius. The entire trochanter may be exposed by carrying the dissection laterally.

UNUNITED FRACTURES OF THE NECK OF THE FEMUR

Stabilization of the hip joint is by far more frequently indicated in ununited intracapsular (or central) fractures of the femoral neck than in any other condition.

When weight is borne on an ununited fracture of the femoral neck, the trochanter is forced up into the gluteal muscles, making fixation of the pelvis impossible. The upward excursion of the trochanter induces marked fibrosis. Pain is usually the outstanding symptom, endurance is always poor, and in most instances, crutches are necessary for walking.

The status of non-union of the femoral neck is reached much earlier than in any other fracture in the body unless efficient joint. The head usually remains intact because of deficient circulation. The neck has a free circulation, which is essential to

Fig. 3. Age 57 years. Combined Brackett reconstruction and shelf operation. Excellent functional result.

Fig. 4. Age 54 years. Albee reconstruction operation. The femoral head was used as a free graft beneath the trochanter which was transferred to a lower level.

treatment is employed at the time of fracture. A delay of four weeks without reduction may usually be regarded as an ununited fracture, and at the end of two months the definite status of non-union exists. Undoubtedly union may rarely be secured by conservative measures even after the elapse of a longer period of time. This has been demonstrated by Zadek, and recently by A. Meyer. However, the successful results obtained by these two men must be considered as exceptions to the general rule.

In the treatment of non-union of the neck of the femur, conservative measures must be reserved for cases in which surgery is refused or contraindicated. In the opinion of the author, radical measures are definitely indicated after the elapse of four weeks.

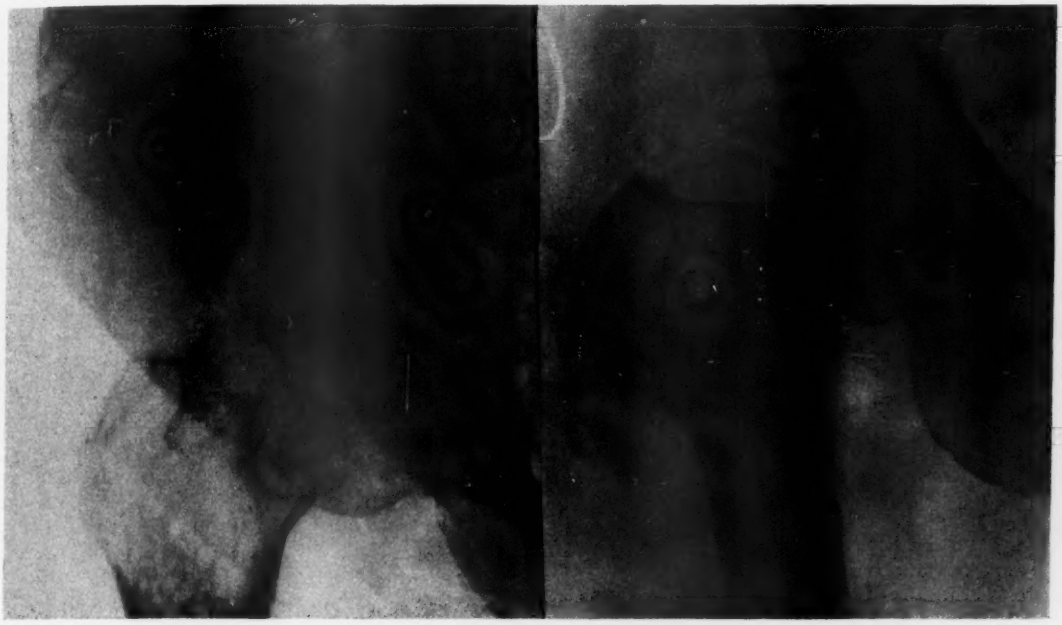
After the lapse of time there is a gradual evolutionary change in all the tissues of the decalcification, and gradually becomes absorbed. After one or two years, only the trochanter and a small portion, if any, of the neck may remain. In time, as the head becomes revascularized, decalcification occurs and in some instances the head disappears.

The strong abductor muscles become contracted and the trochanter is lifted to a higher level, decreasing the length of the limb and further separating the fragments. The posterior ligaments also become contracted, especially the ischiofemoral ligament, maintaining the limb in external rotation and further separating the fragments.

Operative Procedures. The first operative procedure devised for this condition consisted of excision of the head and placing the upper extremity of the neck into the acetabulum. This proved a failure as there was usually dislocation with recur-

rence of the original instability. This procedure was the precursor of the reconstruction operations described below.

union decrease with the lapse of time and the degree of absorption. Bone graft is contraindicated in the aged, as less shock-



A B

Fig. 5. Age 66 years. A, non-union of ten months' duration. B, solid union and excellent function following osteotomy.

Many operative procedures have been devised for non-union in this location, and no one procedure is applicable to all cases. The indications depend entirely on the status of the individual case. Procedures employed at the present time are as follows: (1) bone graft or pegging; (2) internal fixation by metal nails, pins and screws; (3) reconstruction operation of (a) Whitman, (b) Brackett, (c) Albee, (d) L'Episcopo, (e) Colonna, and (f) the author; (4) osteotomies, intertrochanteric and subtrochanteric; and (5) arthrodesis or fusion.

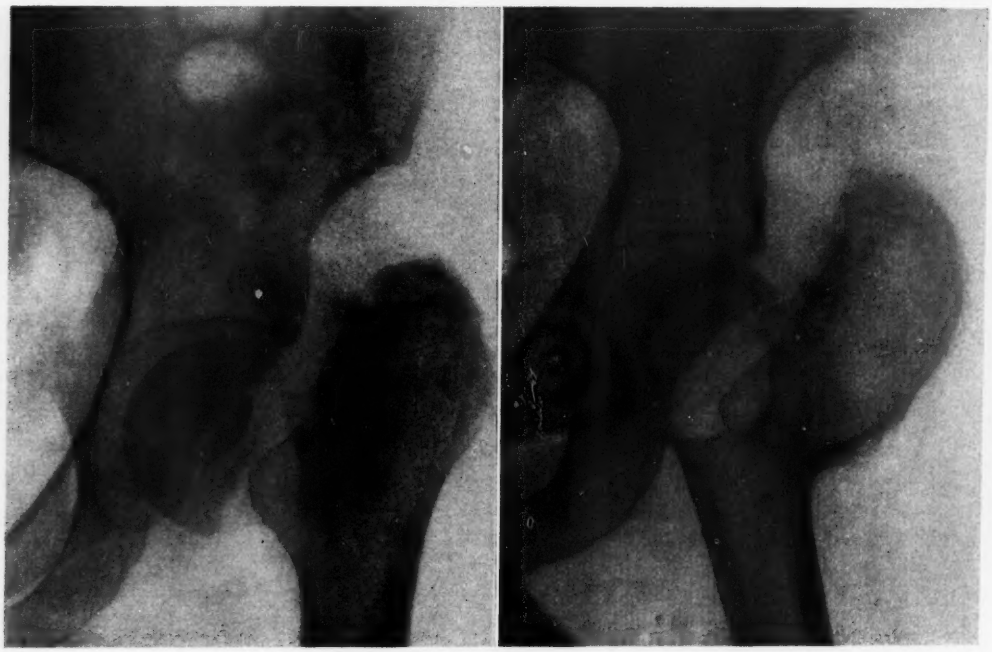
Bone Graft of the Neck of the Femur. When a long proximal fragment and little or no absorption of the neck exists, this procedure offers the possibility of anatomic restoration of the upper extremity of the femur. The operation is particularly advantageous in fairly young individuals with non-union of a few months' duration. Absorption of the neck is not an absolute contraindication, but the chances of solid ing procedures offer excellent function without the necessity for prolonged fixation (six to twelve months).

The operation is best carried out through the approach described by Dupuy de Frenelle, exposing both the trochanter and the fracture site. The fragments are denuded of fibrous tissue and reduced. An autogenous graft from the tibia or a portion of the entire shaft of the fibula is driven through the center of the neck and into the head. By this means, the denuded fragments may be very closely approximated.

In older patients the graft may be inserted by the method of blind pegging, as is now carried out with various pins, nails and screws in fresh fractures.

Prior to the comparatively recent development of the roentgenographic technique for taking two views of the femoral neck, this pegging procedure had to be carried out with the anteroposterior view alone. The percentage of cases in which both fragments were engaged by the graft with

only the anteroposterior *x*-ray control is surprisingly large. Experienced surgeons have reported from 65 to 75 per cent solid bony unions, and a small percentage in which function was improved by a change in position and a strong fibrous union.



A B

Fig. 6. Age 63 years. A, non-union of ten months' duration. B, excellent function despite persistent non-union.

With the two view *x*-ray control that is now possible, bone graft of the femoral neck offers the hope of excellent functional results in carefully selected cases.

Internal Fixation by Metal Nails and Pins. Various metal nails and pins have been inserted by the same procedure as described for the insertion of the graft. There has not been a sufficiently large series by any one surgeon to evaluate the procedure properly. In a small number of cases the procedure has been used by the author. In one case, solid union was secured after two months and in one after eight months; however, in two others the procedure was not satisfactory.

Reconstruction Operations. Several operations for reconstruction of the hip joint have been devised. The exact procedure to be selected depends largely on the condition of the head and neck of the femur.

Whitman excises the head and severs the trochanter with its muscle attachments. The upper extremity of the femur is placed in the acetabulum and the trochanter transplanted lower down on the femoral shaft. Stability is maintained by the stretched abductor muscles.

Colonna excises the head and severs the abductor muscles at their attachment to the trochanter. He places the trochanter with its fibrous investment into the acetabulum, transferring the tendinous fibers of the severed muscles into the shaft of the femur at a lower level. Colonna claims that better motion is secured because of the fibrous investment of the trochanter.

Brackett removes most of the cancellous bone from the head and reshapes the neck, placing the denuded neck in contact with the excavated head. The trochanter with its muscle attachments is transplanted to a lower level on the lateral surface of the femur.

Albee removes the head and splits the greater trochanter from above downward, creating a greenstick fracture at the base of the trochanter. The trochanter with its

muscle attachments is bent laterally and a free graft of bone, either the denuded head or bone from the ilium, is wedged into the space. The medial portion of the trochanter and neck is placed into the acetabulum. No muscle attachments are disturbed, but the relaxed abductor muscles are shortened and their leverage action returned to normal.

Fig. 7. Age 27 years. Traumatic dislocation of thirteen months' duration.

L'Episcopo has recently devised a similar procedure which consists of doing a green-stick fracture of the inner third instead of the outer third.

The author has employed the same principle as that devised by Albee in two instances. The head was excised and shaped into a cube, and the trochanter severed and transferred to a lower level, the cube being inserted beneath the trochanter, thus securing better leverage for the abductor muscles.

The author has had personal experience with all of these reconstruction operations, and undoubtedly excellent results are secured when compared to the patient's former status. Most individuals are able to discard crutches and to attend to the average demands of daily life. In many, the use of a walking cane adds materially to the endurance. In a small number of comparatively young individuals, almost normal activity is restored, but this is the exception rather than the rule.

Osteotomies. Osteotomy of the shaft of the femur is by no means a new procedure for ununited fractures of the femoral neck. This operation was employed by Lorenz as early as 1910, according to the author's personal knowledge, and later by Böhler and others.

Osteotomy may be done at the level of the lesser trochanter, or as advised by Schanz, at the level of the tuberosity of the ischium. The higher osteotomy is more often used in ununited fractures of the femoral neck, and is indicated as early as possible after the status of non-union has been discovered, and before marked absorption of the neck has taken place.

The procedure is carried out through a 3 or 4 inch longitudinal incision over the

lateral surface of the trochanter and adjacent femoral shaft. The most desirable site is selected with *x*-ray control by the

Fig. 8. Same as Figure 7, after formation of new acetabulum at higher level and remodeling of head. Excellent function.

insertion of a drill or Kirschner wire, and the femur severed with an osteotome. The distal fragment is then displaced inward beneath the head and the seat of non-union.

The operation can also be carried out as in the Gant's osteotomy, through a small incision at the base of the greater trochanter. A drill or Kirschner wire is inserted and the site of osteotomy selected by *x*-ray. The osteotome may be inserted on the drill or wire and the osteotomy made from below upward and inward at an angle of about 40 degrees. The lower fragment is displaced medially by manual force and abduction, aided, if necessary, by driving an impactor against the femoral cortex. The distal fragment should be displaced medially at least 1 inch. This can be determined by probing with a periosteal elevator or other blunt instrument, as the upper fragment can be felt to protrude externally. The exact position is confirmed by anteroposterior and lateral *x*-rays, and a plaster cast is applied from the nipple line to the toes of the affected side and to the knee on the opposite side. An anteroposterior roentgenogram should then be made through the cast to confirm the position.

Fig. 9. Age 3 years. Fifteen years after shelf operation for congenital dislocation of the hip.

Even when the open operation is employed, roentgenographic control should be used, as failure to displace the distal fragment accurately defeats the purpose of the procedure.

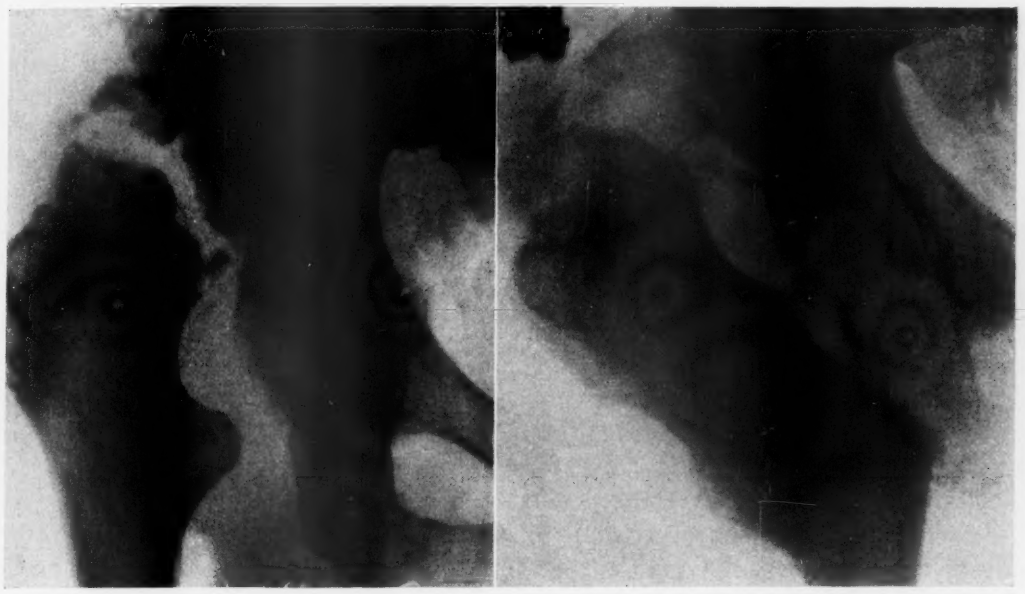
Some surgeons employ transfixion nails in each fragment, incorporating the nails into the cast. This, however, is not necessary, as satisfactory position can be secured with external fixation alone.

The cast is removed at the end of two months and if union is solid, walking may be instituted with crutches or a Thomas caliper brace. Otherwise, a cast is applied with hinges at the knee for exercise of this joint.

The high osteotomy prevents the shearing action at the fracture site by displacing the weight bearing line inward so that the

femur finds a strong bony support above. At the same time the upper fragment is angulated outward increasing the leverage of the abductor muscles.

and the lower fragment is angulated medially so that it contacts the ischium. This position is maintained in a plaster cast until union is solid. The object is stabiliza-



A B

Fig. 10. A, Charcot joint. B, two years following Shantz osteotomy. Good functional result.

Solid bony union is secured at the site of non-union in many cases when the procedure is carried out early, or before there is absorption, or extensive changes occur. Even when bony union is not obtained, a stable, superior, osseous support is secured, which compares favorably with any reconstruction operation so far devised.

When bony union does occur, a most excellent result is secured. The patient may have 50 per cent or more of normal motion and almost normal endurance.

About four years ago, the author began to employ the procedure in debilitated or very aged patients. The results in these patients were so satisfactory that the scope of the procedure has been extended.

As a consequence of the excellent results obtained with this procedure, reconstruction operations are reserved for cases in which there is no neck and in which marked upward displacement of the trochanter exists.

The low, or Schanz osteotomy is made at the level of the tuberosity of the ischium

tion of the pelvis and femur, thus giving, indirectly, a superior support. The procedure is only indicated in those in which the neck has completely disappeared.

Both the high and low osteotomies have been advocated in fresh fractures of the neck of the femur and excellent results have been demonstrated.

The one disadvantage in the Schanz osteotomy is the occurrence of genu valgum as a result of strain on the internal lateral ligament of the knee joint.

The author has not had sufficient experience to evaluate the procedure. The late F. J. Gaenslen and his colleague, Schumm, have demonstrated excellent results in late ununited fractures of the neck of the femur and other mechanically analogous conditions.

Fusion or Arthrodesis. Gill has employed this measure in the treatment of ununited fractures of the neck of the femur with success. But, as Gill points out, a stiff hip should never be induced in the presence of arthritic changes in the spine.

Pathologic Processes Causing Dissolution of the Head or Neck. Dissolution changes in the head and neck of the femur as a result of various pathologic processes may produce exactly the same mechanical status as is found in ununited fractures of the neck of the femur. The causative agents are pyogenic infection, tuberculosis, aseptic necrosis, etc. If there is sufficient head and neck, a modified arthroplasty may be carried out, with restoration of the acetabulum of sufficient size to maintain the reconstructed head. At the same time a longitudinal osteotomy of the trochanter and outer third of the shaft may be made with displacement outward of the fragment, filling the space with a graft from the ilium. Mechanically, this elongates the neck and restores more normal leverage for the abductor muscles. When there is no head or neck, reconstruction operation, or osteotomy, or fusion, as above described, may be employed.

Congenital Dislocation of the Hip. In congenital dislocations which have passed the age in which satisfactory reductions are possible, three types of operation have been advised: (1) formation of a shelf on the dorsum of the ilium to give support to the head; (2) the formation of a new acetabulum and a shelf above the site of the normal acetabulum; (3) Lorenz bifurcation osteotomy. In the first two a satisfactory result, as emphasized by Dickson, requires the placement of the head forward on the dorsum of the ilium in line with the normal acetabulum. The results of this procedure, in our experience, after the elapse of six months to one year, were apparently unsatisfactory, but after two or more years proved to be surprisingly good. The Lorenz osteotomy or bifurcation operation consists of an osteotomy at the site of the acetabulum, from without, inward and upward, which has been modified by Haas from below upward and forward, avoiding any danger of injury to the femoral vessels. The lower fragment is displaced into the acetabulum in abduction, and union is secured between the two fragments. Putti, who is a strong advocate of this measure, and has had more experience in congenital dislocations than any living individual, states that the operation should not be done before the age of 15, for before this period growth may nullify the mechanical effects.

In traumatic dislocations of long duration, as in old congenital dislocations, reduction is impossible, and the following operative procedures are usually advised: (1) the acetabulum may be enlarged upward and the head made smaller, after which reduction may be accomplished. Excellent motion is usually secured, but stability is far from satisfactory. A fusion of the hip, if the patient will submit, would be more desirable. (2) The second type of operation is the Lorenz or Schanz osteotomy.

Paralytic Dislocation of the Hip. In paralytic dislocation the problem confronting the surgeon is maintaining the head of the femur within the acetabulum and giving it ample superior support. Reduction is never difficult; in fact this can usually be accomplished by the patient.

Many operative procedures have been devised to stabilize the paralytic hip, most of them based on the principle of the shelf operation mentioned above. The following procedure was devised by the author and has been employed for many years with satisfactory results. A curved wood-carver's chisel is inserted above the acetabulum, breaking loose the entire superior portion with the articular cartilage attached; this is then pulled outward, extending the roof of the acetabulum laterally. Osseous flaps of raw bone are turned down from the dorsum of the ilium and one massive graft is removed from the crest of the ilium and forced into space above the extended acetabulum. Osseous union of the grafts with the acetabulum usually occurs in about sixty days, thus giving support to the upper extremity of the femur with material restoration of function and increased efficiency. This definitely improves the limp and also increases endurance, but the paralysis remains as a potential dis-

ability. In certain cases, the stability of the hip may be further improved by muscle transplantation at the same operation, or later, as devised by Legg and Dickson and others. When the tensor fasciae femoris is active it is transferred to the posterior portion of the crest of the ilium.

Charcot Joints. Charcot joints are an exceedingly difficult problem, and the results of surgery far from satisfactory. On account of the osseous structure fusion is improbable. Reconstruction operations may materially improve ambulation, but rarely is permanent relief secured. Probably the Schanz osteotomy, which is done in an area of normal bone, offers the greatest hope. The author has secured an apparently satisfactory result in only one case by this method.

CONCLUSIONS

Operations for stabilization of the hip are legion, on account of the great frequency of occurrences of the various agents which induce instability. No one procedure can be adopted in all cases but proper surgical measures must be selected to meet the requirements of the individual case. Low and high osteotomies are at present being extensively employed with the report of favorable results, but more time is required before the actual status can be determined.

THE importance of being slender is greater than surface beauty . . . The thin are healthier and happier and live longer.

SURGERY OF THE FOOT IN INFANTILE PARALYSIS

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THE predominant purpose underlying surgical operations on the foot is to restore, as far as possible, the function of the foot in standing and locomotion. This presupposes an accurate knowledge of the anatomic structures of the leg and the foot, the muscles, the bones and the joints with their ligaments, and a comprehension of the mechanical function of each structure alone and in coördination with all the others.

In anterior poliomyelitis, commonly known as infantile paralysis, there may occur a partial or a complete paralysis of one muscle or even of all muscles of the leg. While the physician in charge of the patient during the acute and the convalescent stages of the disease endeavors by proper splinting to put the weakened muscles at rest and to prevent the development of deformities, and while he endeavors during the stage of recovery to restore power to the affected muscles by suitable exercises and other methods of treatment, yet the patient frequently arrives at the final stage with certain residual and permanent paralysis. The problem then becomes a purely orthopedic one.

DEVELOPMENT OF DEFORMITIES

Deformity of the foot develops. This is due essentially and primarily to muscle imbalance. Its form and its severity are entirely dependent on the extent and the degree of muscle weakness and paralysis.

A muscle which is unopposed or but feebly opposed by its natural antagonist will pull the foot in a definite direction. This pull is a constant one because it is caused by the normal physiologic tone or contraction of the normal muscle fibers and is entirely independent of any volitional activity of the muscle. At first the muscle contraction and the resulting deformity are functional. The muscle can be stretched and the deformity overcome. But as time passes both become structural and permanent. This is due to the fact that when a muscle is permitted to remain in a continued state of contraction its fibers become structurally shortened and cannot be stretched and elongated to the normal extent. The foot, or certain parts of it, thus become fixed in an abnormal position. If the opponent muscles had any residual power they lose it because of the constant overstretching of their fibers.

The bones of the foot, particularly in the rapidly growing child, will soon become altered both in their shape and their architecture in accordance with Wolff's law. The ligaments of the joints become elongated on one side and shortened on the opposite side. Thus, eventually the deformity involves the essential structures of the foot and it may no longer be corrected by lengthening contracted muscles.

The malposition of the foot, while due primarily to muscle imbalance, is exaggerated by the bearing of the body weight. The foot is not placed properly beneath the weight-bearing line and the superimposed load thrusts it still farther away from this line in the direction of the primary deformity.

The development of deformity of the foot is accompanied by a corresponding impairment of function. The instability of the foot and the abnormal strain upon that part of the foot which is obliged to bear the entire weight of the body because of the shift in the weight line make standing and walking difficult. And, because the function

of one or more muscles has been destroyed, the normal power and elasticity of locomotion is impaired. The development of painful calluses at the sites of friction and pressure still further adds to the disability of the foot.

DESCRIPTION OF DEFORMITIES

Deformities of the foot can arise because of the natural movements which are possible in its joints. (This, of course, is aside from malpositions which occur because of fractures, dislocations and loss of bony substance.) When any joint becomes fixed in any other than the normal position for weight bearing and locomotion or when it assumes a position which is beyond the individual's control on standing and walking, we call this condition a deformity. Some deformities are constantly present while others are apparent only when the person puts his weight on his foot.

Physiologic Movements of the Foot. The movements of the ankle joint are best designated as *dorsal* and *plantar flexion* (bending) of the foot. This avoids the confusion which may arise by calling plantar-flexion extension of the foot, inasmuch as it is produced by the flexors of the ankle and the toes, and the opposite movement (erroneously called flexion of the ankle) is produced by the extensors of the ankle and the toes.

Supination and *pronation* correspond with the similar movements of the hand and occur when the os calcis and the scaphoid rotate around the longitudinal axis of the astragalus. The calcaneo-astragalar and the astragaloscaphoid joints move in unison during this function and therefore are considered surgically as one, the subastragalar joint.

Inversion (internal rotation) and *eversion* (external rotation) also occur in the subastragalar joint.

Adduction and *abduction* denote movements of the forefoot and take place in the midtarsal or Chopart's joint (the astragaloscaphoid and the calcaneocuboid joints).

Plantar and *dorsal flexion* of the anterior part of the foot also occur largely in the midtarsal joint.

Certain of these movements of the foot may occur in coördination with one another, such as inversion and supination, eversion and pronation, etc.

The movements of minor joints need not be considered here.

The author may add that there is considerable confusion in textbooks concerning the use of these terms and that supination and inversion or inversion and adduction are used synonymously, for example. This may all be avoided by adherence to the above nomenclature.

DEFORMITIES OF THE FOOT

Talipes Equinus. Plantar flexion on weight bearing, due essentially to contracture of the tendo Achillis, is complicated at times by contracture of the posterior ligament of the ankle, deformity and subluxation of the ankle and contracture of the flexors of the toes. The author has seen this deformity so severe that the patient bore her weight on the dorsum of the foot and wore a shoe with the toe pointing backward behind the leg.

Talipes Calcaneus. This is dorsal flexion or heel walking, and may be so severe that the heel lies in front of the weight-bearing line of the tibia. Often combined with marked cavus (hollow foot).

Talipes Valgus. Pronation and eversion of the foot. Weight is borne largely or entirely on the inner side of the foot.

Talipes Varus. Supination, inversion and, sometimes, adduction of the foot. The opposite of valgus.

Talipes Cavus. Hollow foot. The top of the arched foot is at the midtarsal joint. By some authors this deformity is divided into two types: (1) *arcuatus*, in which the os calcis is tilted upward in front and the forefoot is dropped; and (2) *plantaris*, in which the forefoot drops at the midtarsal joint, but the os calcis is in normal position, or even tilted downward in front.

Talipes Planus. Flatfoot. This often accompanies valgus.

Talipes Adductus. Adduction of the forefoot. Concavity of the inner side of the foot.

Flail Foot. Complete paralysis of the foot. Dangle-foot.

Drop Foot. Either a dangle-foot or a talipes equinus.

Claw Foot. Prominence of heads of metatarsals, hyperextension of proximal phalangeal joints and flexion of interphalangeal joints, combined at times with some degree of cavus.

Various combinations of these deformities may be present, as calcaneovalgus, calcaneocavovalgus, equinovarus, etc.

Furthermore, lateral deformity may occur in the ankle joint. When a valgic foot has been subjected to long-continued weight bearing the outer portion of the astragalus is narrowed from top to bottom. When the foot is plantar-flexed the valgus disappears because the outer part of the astragalus drops down within the ankle joint and the outer portion of its articular surface is no longer in contact with the tibia. On dorsiflexion the outer part of the astragalus ascends and the foot goes into valgus. There is a rotation of the astragalus within the mortise of the malleoli.

It must be remembered that all of these various types of deformity arise primarily from muscle imbalance and that after surgical correction they may recur if balance is not restored.

The surgeon should have a thorough knowledge of the normal construction and mechanics of the foot and an understanding of the causes and the elements of the various deformities and disabilities before he attempts reconstructive operations.

Orthopedic surgeons have made many mistakes in the past. Many operations at one time popular have now fallen into disuse because they were not fundamentally sound. It has taken a good many years of observation and study to evaluate the various surgical procedures that have been proposed and employed and to design new ones better fitted to secure permanent correction of deformities and optimal restoration of function.

OPERATIVE PROCEDURES

It will be impossible in a paper of moderate length to enumerate and describe all the operations that are employed in treating the deformities and disabilities of the foot caused by infantile paralysis, and to give due credit to all surgeons who have made contributions in this field of surgery. Attempt will be made to state and explain the principles underlying the various types of surgical procedures and to mention those pioneers who enunciated them or aided essentially in establishing them in operative surgery; to illustrate their application in the correction of the common deformities and to point out not only the uses but also the abuses of standard operations.

Tenotomy and Fasciotomy. Stromeyer usually receives the credit for establishing the value of tenotomies in the correction of contractures. His method of subcutaneous division of the tendo Achillis enabled him usually to avoid the infections which almost invariably followed the open operations in use in his time, and, consequently, tremendously broadened the field for this procedure.

Its purpose is to secure a definite lengthening of a structurally shortened muscle in order to correct a deformity which is due in whole or in part to the contracture of this muscle. Other structures such as fasciae, ligaments and capsules of joints and malformed bones may resist and prevent correction after tenotomy has been done.

Tenotomy does not increase the power nor extend the function of the muscle. The range of tendon movement is less than normal because the shortened (contracted) muscles fibers have not been lengthened. Muscle strength is likewise subnormal because these same fibers are in a state of physiologic contraction and cannot undergo further volitional shortening to produce movement. Therefore, an overlengthening of the tendo Achillis to correct equinus may

lead to the more disabling deformity of calcaneus. Possibly, too, the dorsiflexors of the foot may recover some power on relief of the overstretching which has been produced by the prolonged plantar flexion of the foot and contribute to the production of calcaneus. On the other hand, the original deformity may recur if the triceps surae is still in the process of structural shortening or if the bones of the leg are growing longer.

Therefore, tenotomy of the tendo Achillis to relieve a disabling talipes equinus should not be performed during the earlier period following the attack of infantile paralysis. It should be done only when a lengthening of the muscle fibers cannot be obtained by manipulation, sufficiently gently to avoid rupture of muscle substance, or be secured by gradual stretching by the use of apparatus or turnbuckle casts.

Overlengthening may be avoided by the open z method of lengthening with suturing together of the two ends after the desired correction of the deformity has been made. An equally effective result may be obtained by subcutaneous divisions of the two halves of the tendon at the desired distance from each other and forcible stretching to cause one half to slide upon the other to the necessary extent.

There are comparatively few cases following infantile paralysis where an equinus is not combined with a lateral deformity of the foot. In these cases the tenotomy must be accompanied or succeeded by a foot stabilizing operation. And, since a subastragalar arthrodesis produces some bony shortening below the ankle with relative lengthening of the tendo Achillis, a tenotomy may be unnecessary.

It should be borne in mind that a moderate fixed equinus aids in stabilizing the knee in cases of paralysis of the quadriceps femoris muscle.

In conclusion, one may say that tenotomy or formal lengthening of the tendo Achillis is not indicated except in children who have not yet reached the age when arthrodesis may be done or in combination with this latter operation at the proper time.

Tenotomy or even resection of other tendons, for example, the peronei and the tibialis posticus, may be indicated in the correction of lateral deformities or for the prevention of relapse.

Fasciotomy of the plantar fascia is useful in the correction of hollow foot. The author subcutaneously cuts the fascia free from its attachment to the internal tuberosity of the os calcis. Many surgeons use the open stripping method of Steindler.

Muscle Transplantations and Transferences. One of the earlier developments in the modern surgical treatment of infantile paralysis was the attempt to restore muscle balance of the foot by transplanting the insertion of muscles or by transferring the direction of their action by the formation of a pulley around which the tendons would glide. The names of Nicoladoni, Codivilla, Vulpius, Lange, Mayer, Steindler, and others stand out in this field.

In the course of a few years outstanding limitations and contraindications to these methods of operation became apparent. It was very difficult to reëstablish a complete muscle balance. To estimate accurately the exact mechanical power of any muscle or group of muscles is painstaking and dubious. To compute its power and its physiologic function when transplanted to a new position is even more difficult. And to find a muscle which after transplantation is of just the precise strength to balance the foot against its antagonist, if it then has an antagonist, is practically impossible. The entire matter is exceedingly complicated.

Tendon transplantation presupposes also that all other elements of the deformity are first eliminated, as a transplanted muscle will not overcome contracted ligaments and muscles and correct malshaped bones.

The technique of operation is exacting in order to preserve as far as possible the normal direction of pull of the tendon, to maintain the normal tone of the muscle fibers which might be disturbed by over-

stretching or over-relaxation, to prevent adhesion of the tendon to surrounding structures and to avoid injury to its blood supply, as well described by Mayer.

A transplanted muscle may be able to produce volitional movement when the foot is at rest, but may be inactive during the act of locomotion. It may not act in coördination with all other muscles, as it does naturally when in its normal position.

A transplanted muscle may lose some of its natural strength because of a too great load placed upon it.

No wonder that failures to secure correction and that relapses and overcorrections and development of new deformities from added disturbance of equilibrium so frequently followed these operations.

Generally speaking, therefore, muscle transplantation and transference is useful only in combination with other corrective and stabilizing types of operation. It is necessary even after fusion, or arthrodesing, operations to have some semblance of muscle balance in the foot lest the original deformity recur. The author, years ago, called attention to the lateral deformity which may develop in the ankle joint following effective subastragalar arthrodesis and due to the continued pull of the pronators and evertors of the foot. When the normal mechanical function of a muscle is destroyed by a fusion of the joint which that muscle moves, the tendon should be transplanted to a position where it may have a useful function. This principle will be illustrated later.

Neurotization. To reënervate paralyzed muscles would be the ideal treatment. This procedure has been investigated by Erlacher and others; but insuperable difficulties have been encountered that, thus far, render it impracticable.

Tenodesis. The fixation of a tendon into bone to make it serve as a ligament to prevent or to limit certain movements of the foot has been employed by Codivilla, Putti, Gallie and others. The most useful field of tenodesis has been in the correction of talipes calcaneus either alone or, preferably, in combination with other operative procedures that produce backward displacement of the foot and also correct lateral instability.

Arthrodesis, or Fusion of the Foot. Fusion of two or more bones of the foot is performed to correct deformity and to effect a permanent stabilization in the normal weight-bearing position with regard to the foot as a whole in relation to the leg and with regard to the position of the bones of the foot in relation to one another. Arthrodesis is often the only means that will accomplish these two objectives. Part of the flexibility of the foot is sacrificed for stability which is so essential for weight bearing. Joint motions in the foot are of no practical value unless they can be controlled or unless the bones remain in normal relation to one another on standing and walking.

Arthrodesis of the Ankle. Albert originated this operation in 1878, and the technique has been frequently modified by other surgeons. It was used chiefly to correct talipes calcaneus. Of course, it has applications other than in infantile paralysis, but this paper is dealing only with the latter. After Whitman (1901) and Davis (1913, 1916) showed the value of posterior displacement of the foot in the correction of calcaneus, arthrodesis of the ankle fell for the most part into disuse.

It has certain vital defects except in a limited number of cases. The foot is converted, in effect, into a peg-leg, rigid and inelastic. This objection may in part be overcome if the foot is ankylosed in slight plantar flexion so that the ball of the foot may first strike the ground and permit the movement of the tarsal joints to compensate for the absence of movement in the ankle, and to permit the wearing of a shoe which has a heel of the usual height.

Since calcaneus is frequently accompanied by lateral deformity and cavus, arthrodesis of the ankle will not solve the whole problem. Other operations, such as the Whitman astragalectomy or the Davis horizontal transverse section with back-

ward displacement of the foot, will correct all elements of the deformity.

The employment of arthrodesis to correct the drop of the flail foot is ill-advised, as there are better operations for this condition.

Ankle arthrodesis may be useful, as taught by Davis, in stabilizing the knee when the quadriceps femoris is paralyzed. If the ball of the foot first strikes the ground while the ankle is fixed the weight of the body tends to force the heel downward and drive the knee backward. A moderate contracture of the tendo Achillis produces the same mechanical effect.

Steindler's panastragalar arthrodesis is a fusing of the ankle and the subastragalar joints. The indications for these two operations (ankle and subastragalar arthrodeses) are entirely separate and distinct. The author has objected to Steindler's nomenclature as tending to confuse and obscure the essentially different and clearly defined indications for the two operations. Furthermore, the term is superfluous, as each of the two operations was already firmly established among surgical procedures. And, finally, the combination of the ankle and subastragalar fusions renders the foot more rigid than may be necessary.

On the whole, the author believes that arthrodesis of the ankle has little or no place in reconstruction operations on the foot in infantile paralysis.

Subastragalar Arthrodesis. This is probably the most useful of all operations on the foot. While the literature demonstrates that Nieny first advocated it (1905) yet G. G. Davis independently originated an operation to stabilize the foot by this method. He published his first paper in 1913, but the author has found in the records of the Orthopaedic Hospital in Philadelphia a description of the operation written in 1907 in his own handwriting together with pencil sketches to illustrate it. Davis, probably, was most influential in establishing the principles underlying the operation and in demonstrating its usefulness, and during a time when other surgeons in America were doubting or denying its efficacy and were still using tendon transplantation and tenodesis only in the operative correction of deformities except for an occasional arthrodesis of the ankle by the method of Goldthwait (1908).

Numerous modifications of Davis' method and different ways of performing the arthrodesis have been devised since Davis' earlier work, but all have for their one object the fusion of the astragalus, the os calcis and the scaphoid in the position essential to normal weight bearing. It is useful in the permanent correction of the lateral deformities of the foot and in the stabilization of flail foot.

Arthrodesis of the subastragalar joint by any operative method is accomplished by completely removing the articular cartilage from the three bones which enter into this joint. The forefoot is then placed in proper alignment with relation to the longitudinal axis of the astragalus and the os calcis, which carries the forefoot with it, is set normally beneath the astragalus. The foot is maintained in a plaster cast for a period of twelve weeks until the fusion is accomplished. Great care must be taken by any method to mould the foot properly before the plaster sets.

Lateral muscles such as the peroneus brevis and the tibialis posticus, if strong, must be resected or transplanted to positions where they may be useful in active plantar or dorsiflexion of the foot. The arthrodesis destroys their natural function, and they should not be left to bring about any recurrence of lateral deformity.

Arthrodesis should usually be postponed, if possible, until the child has reached the age of 9 to 12 years, as before this period the bones are too cartilaginous in their structure.

When the lateral deformity of the ankle, which has already been described, is present, the author corrects it by raising the superior articular cartilage of the astragalus from the outer side and inserting into the cleft a wedge-shaped piece of bone removed from the astragalus or the os

calcis while doing the subastragalar arthrodesis. Thus the normal shape of the astragalus is restored within the mortise of the ankle.

The triple arthrodesis of Ryerson consists of a subastragalar plus a calcaneocuboid arthrodesis. It is useful in lateral deformity accompanied by talipes cavus, extreme planus or adductus.

The Correction of Talipes Calcaneus. Whitman (1901) first demonstrated the necessity for displacing the foot backward below the ankle. He accomplished this effectively by removing the astragalus (astragalectomy). The tibia was then brought forward to rest upon the foot near the midtarsal joint. The peroneal muscles (when valgus was present) were transplanted into the os calcis. The talipes cavus was corrected when the foot was displaced backward. When this operation has been confined to those cases of calcaneus and calcaneovalgus for which Whitman designed it the results have been very satisfactory. Its efficacy depends on several factors: (1) the displacement of the tibia forward prevents the anterior part of the foot from tilting upward; (2) the tarsus comes in contact with the anterior lip of the tibia and acts as a bone-block to dorsiflexion; and (3) the ligaments of the ankle as they are displaced backward by their attachments to the foot act as posterior check ligaments. The transplanted peronei may partially restore muscle balance of the foot.

Davis, by his horizontal transverse section and backward displacement of the foot beneath the astragalus, applied the main principle of the Whitman astragalectomy without removing the astragalus and at the same time (by the subastragalar section, or arthrodesis) corrected the lateral deformity. The head of the astragalus is removed in this operation to permit the backward displacement of the foot. The peronei, if active, are transplanted to the os calcis. The author has modified the Davis operation by definitely stripping the lateral ligaments of the ankle (particularly the external) from the lower portion of the malleoli, so that they will form strong posterior check ligaments, and by elevating the anterior superior articular cartilage of the astragalus and fixing it with a bone wedge to constitute an anterior ankle block in severe cases.

The Whitman and the Davis operations are both fundamentally sound and both will give splendid results if properly executed. Other operations based upon the same principles have been devised by a number of surgeons.

Putti (1922) also devised a method of constructing an anterior bone-block at the ankle.

Flail or Dangle-Foot. In this condition there is a complete paralysis of all muscles. The anterior part of the foot drops of its own weight, when it is raised from the ground. On weight bearing it turns frequently into a position of varus or valgus and is therefore unstable, although no fixed deformity is present in non-weight-bearing position.

Such a foot is well stabilized by a subastragalar arthrodesis and a moderate backward displacement of the foot to balance more nearly the heel with the anterior part of the foot.

Drop Foot and Posterior Bone-Block. The foot may drop either in the condition of flail foot just described or in the true talipes equinus (power in the tendo Achillis and paralysis of the dorsiflexors).

For the latter condition a posterior ankle bone-block is essential. Campbell first described (1923) a suitable operation for this deformity. He builds on the posterior superior aspect of the os calcis a mass of bone that by contact with the posterior and inferior surfaces of the lip of the tibia prevents plantar flexion of the foot.

The author described (1933) another method to accomplish the same result. The posterior half of the articular cartilage of the astragalus is lifted up and held firmly against the inferior surface of the tibia with a bone wedge driven in solidly beneath the cartilage. This wedge is removed from the

posterior superior part of the os calcis. It is the same method by which the author had been accustomed to make an anterior bone-block.

Talipes Cavus. This deformity occurs in the midtarsal joint and may be efficiently corrected by a midtarsal arthrodesis with the excision of sufficient bone from the surfaces of the astragalus and the scaphoid and from the os calcis and the cuboid to permit complete correction.

In very young individuals the deformity may be cured by a division of the plantar fascia at its attachment to the tuberosity of the os calcis and a manual manipulation of the foot.

The severe cases require both a fasciotomy and an arthrodesis.

Talipes Planus. The severe and disabling type of flaccid flat foot can be cured by astragaloscaphoid arthrodesis with moulding of the foot.

CONCLUSION

The author has tried to make clear the fundamental principles of the various common deformities of the foot in infantile paralysis and to describe, briefly, within the limitations of this paper, certain operations which are in general use and are successful because they were devised and executed in conformity with these principles. Space has not permitted to give due credit to the many surgeons who have contributed essentially to the development of this field of surgery and who have aided in establishing it upon a firm basis.

It must be remembered that a paralyzed foot, no matter how free of deformity or how well stabilized, is never as good as the normal foot, and that the object of all operations, whatever method the surgeon may employ, is to bring about, as far as possible, a return of the foot to its normal appearance and its normal weight-bearing function.

The surgeon is advised to study carefully the literature on this subject that he may be familiar with the underlying principles and with the operative technique. A brief bibliography is appended which should serve but as a basis for much more extensive reading.

REFERENCES

Biesalski, and Mayer. Die physiologische Sehnenverpflanzung. Berlin, 1916. Julius Springer.

Campbell, W. C. An operation for the correction of "drop foot." *J. Bone and Joint Surg.*, pp. 815–825, 1923; and later publications.

Davis, G. G. The treatment of hollow foot. *Am. J. Orthop. Surg.*, pp. 231–242, 1913.

Dunn, N. On stabilization operations in the treatment of paralytic deformities of the foot. *Proc. Roy. Soc. Med.* (Sec. Orthop.), 15: 15, 1922.

Gallie, W. E. Tendon fixation in infantile paralysis. *Am. J. Orthop. Surg.*, pp. 18–29, 1916.

Gill, A. B. End results in the operative procedures for infantile paralysis, with special reference to tendon transplantation, etc. *J. Orthop. Surg.*, pp. 677–688, 1921.

Gill, A. B. Fusion operations on the foot. *J. A. M. A.*, pp. 1829–1833, 1927.

Gill, A. B. An operation to make a posterior bone block at the ankle to limit foot drop. *J. Bone & Joint Surg.*, pp. 166–170, 1933.

Goldthwait, J. E. An operation for the stiffening of the ankle-joint in infantile paralysis. *Am. J. Orthop. Surg.*, p. 271, 1908.

Hoke, Michael. An operation for stabilizing paralytic feet. *J. Orthop. Surg.*, p. 494, 1921.

Mayer, L. The physiological method of tendon transplantation. *Surg., Gynec. & Obst.*, pp. 182–192, 298–306, 472–481, 1916; and later publications.

Morton, D. G. The Human Foot. New York, 1935. Columbia University Press.

Nieny, K. Zur behandlung der Fuss deformitaeten bei Ausgedehnten Laehmungen. *Arch. f. Orth. Unfall. Chir.*, 3: 60, 1905.

Putti, V. Rapporti statici fra piede e ginocchio nell arto paralitico. *Chir. d. organ. di movimento*, 6: 125, 1922.

Ryerson, E. Arthrodesing operations on the feet. *J. Bone & Joint Surg.*, pp. 453–471, 1923.

Steindler, A. The treatment of the flail ankle, panastragaloid arthrodesis. *J. Bone & Joint Surg.*, p. 284, 1923.

Vulpius, O. The Treatment of Infantile Paralysis. New York, 1912. William Wood and Co.

Whitman, Royal. The operative treatment of paralytic talipes of the calcaneal type. *Am. J. M. Sc.*, pp. 593–601, 1901.

Willard, DeF. P. Subastragalar arthrodesis in lateral deformities of paralytic feet. *Am. J. Orthop. Surg.*, p. 323, 1916.

TENDON TRANSPLANTATION IN THE UPPER EXTREMITY

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I. PRINCIPLES

IN the first period after its introduction in the early nineties tendon transplantation had a strong attraction for the orthopedic surgeon, with the result that it became applied much too promiscuously and soon after fell into disrepute. However, in the course of years, the restrictions and limitations of the method had become well established by long clinical studies and extensive experimental work. There are restrictions which apply to tendon transplantation in general; and there are, in addition, others which apply to the upper extremity in particular.

The principles which govern the practice of tendon transplantation are so well established and are so consistently cited in all treatises on the subject that it is hardly necessary to refer to them at great length.

1. A previously existing contracture must be completely corrected because no tendon pull can prevail against an already established shortening of muscles or other soft tissues. It must be possible, after the tendon transference is performed, to bring the limb passively through the range of motion without the slightest resistance.

2. The muscles must be properly chosen. Long and parallel-fibered muscles are particularly suitable for transplantation. The muscle selected for replacement should have a similar or otherwise related action. The use of a straight antagonist as a substitute is somewhat doubtful because of the difficulty in rearranging of voluntary impulses through the central nervous system.

What is the possibility of reëducating the muscle to its new function? In the upper extremity fortunately the movements are so complex that almost every one of the long muscles has a part with some component or other of its function in almost any motion of the wrist; if it is not actually engaged in producing the motion it may function as a stabilizer of the wrist. Consequently, in the upper extremity the possibility of reëducating the muscle is vastly greater than in the lower extremity, and there is, consequently, a greater latitude in selecting muscles for transplantation.

On the whole, however, it may be said that the natural function of the muscle should not be radically changed when it is used for tendon transplantation, and it is believed (Scherb) that the presence of an active antagonist is an obstacle to the transplanted muscle.

3. The integrity of the muscle unit must be respected. It is not possible to educate portions of the same muscle to act as antagonists against each other; in other words, to reverse the action of part of the muscle. This has been tried by splitting the tendo Achillis in the hope of letting one half act independently of and antagonistically to the other half. This is a physiologic absurdity which never does lead to an operative success.

4. The transplanted muscle must have adequate muscle power; that is to say, it should in strength compare favorably with the one for which it is to substitute. As a rule this can be accomplished only approximately. But it is more important in the lower than it is in the upper extremity because weight bearing is a very exacting demand and because stability plays such an important part in the function of the joint; so that, unless the transplanted muscle is at least approximately equal to the one it substitutes, stabilization becomes insufficient and deformity follows. One should always keep in mind that in the long muscles, because they run almost parallel to the long axis of the limb, the stabilizing component is always greater than the

rotatory component which carries out visible motion. In the upper extremity the problem of stabilization is much less important than that of mobilization. Therefore, muscles can be used for mobilizing the wrist or fingers which would be otherwise entirely inadequate for stabilizing purposes; for instance, the palmaris longus can be used for the abductor of the thumb. In other words, the fact that in the upper extremity the stabilizing element is in the background makes the application of tendon transplantation much wider than in the lower.

5. The Leverage. In the mechanical arrangement of the transplanted tendon one must take care that the tendon pull is in a straight line, or, if the line of pull changes direction, it must be so deflected by a pulley through which the tendon may glide freely. This is particularly important in the upper extremity where the system of pulleys and vincula, which ordinarily deflect tendons from a normal course, may be imitated by surgical reconstruction. For instance, in the tendon transplantation of Bunnell for the substitution of the paralyzed thenar muscle, use is made of an artificial pulley constructed at the pisiform bone through which the deflected tendon or deflection of carpi ulnaris is led to the base of the thumb.

It is because it is so important to provide straight lines of pull that we have to use long incisions, so that the tendon may be mobilized sufficiently and may follow a straight course without kinking. Such mobilization of the tendon, of course, interferes somewhat with the blood supply which it receives from the surrounding tissues. This disadvantage, however, can be avoided by carefully refraining from stripping the tendon and by taking along as much of the gliding apparatus, the paratenon, as possible.

6. The next requirement is that the tendon must be transplanted under suitable tension. It is obvious that if the tendon is relaxed in the position in which it is anchored, not much further contraction of the tendon can be accomplished, and, therefore, the range of motion from that position may be small. The tendon should always be given a suitable tension, and even under anesthesia a certain degree of moderate tension should be applied in the position in which the tendon is sutured. It is a rather empirical matter to decide upon the degree of tension. It depends largely upon the amount of antagonistic muscle which is present. For instance, if we transfer a tendon from the flexor group to the dorsum of the wrist, and if the remaining flexors are acting strongly, it is obvious that a greater amount of tension is necessary than in the cases where the wrist flexors are of lesser strength. The increased tension of the tendon makes the joint more set, more closely knit, so to speak. There will be a greater range of motion where both flexors and extensors will be under a certain degree of positive tension, one group relaxing and the other increasing its tension, according to which direction motion is carried out.*

7. Anchorage. The type of anchorage which is now universally preferred is the periosteal or bony attachment of Lange, wherever such anchorage is possible. That is to say, the tendon should be anchored preferably in the bone by means of a drill hole canal.

In the upper extremity it is often necessary to attach tendon to tendon because the transplanted tendon is not long enough to reach to the point of attachment. It has been argued that the paralyzed tendon stretches, but this opinion is lacking in proof, and stretching occurs rather in the paralyzed muscle belly. Where stability is of secondary consideration such tendon attachment is entirely sufficient. It is not sufficient, however, in the lower extremity where the periosteal or transosseous attachment is definitely to be preferred. Where tendon-to-tendon attachment is carried out the best way of anchorage is through the button-hole suture, leading the tendon

* Steindler, A. Mechanics of Normal and Pathological Locomotion. (Thomas, 1935.)

through an opening in the receiving tendon and then anchoring it by lateral sutures. For end-to-end suture we definitely prefer the technique of Bunnell.

8. The Gliding Apparatus. It is essential to preserve the gliding apparatus for the tendon, as a tendon deprived of a gliding surface is not suitable for function. This has been brought out by Codivilla who originated the so-called tendon sheath exchange method, recognizing the importance of the preservation of the sheath for the gliding action of the tendon. Biesalski and Mayer subsequently elaborated the tendon sheath exchange technique, and Bernstein has gone so far as to advocate the transference of the tendon together with the sheath. One must decide how far one should go in the surgical reconstruction of the gliding apparatus and how far nature itself can provide for it. We find that in the upper extremity sufficient gliding facilities are provided when the tendons are led through subcutaneous tunnels. Adhesions are much more likely to follow if the intraosseous route is taken, for instance, between the forearm bones or if the tendon is placed tightly under the vaginal fascia.

II. THE APPLICATION OF TENDON TRANSPLANTATION TO THE UPPER EXTREMITY

In the upper extremity there are certain definite situations suitable for tendon transference.

A. The Substitution for the Paralyzed Deltoid. The first prerequisite is the preparatory correction of the adduction or inward rotation contracture. Conservative methods are to be preferred. These contractures are on the whole of lesser importance and only seldom require operative release of the adductors, i.e., the pectoralis major and the latissimus dorsi, or of the inward rotators, especially the subscapularis. At present we have no reliable method of tendon transplantation for the paralyzed deltoid, and we, therefore, on the whole prefer the arthrodesis of the shoulder joint. However, the newer technique of the method of Mayer as well as the transplantation method of Ober promise fairly good substitution for the paralyzed deltoid.

Mayer's technique is essentially mobilization of a portion of the trapezius and implantation of this portion into the insertion of the deltoid muscle.

Technique. (1) From a longitudinal incision the acromial portion of the trapezius is mobilized. (2) It is then enveloped in a fascial sheath in such a manner that the portion of the fascia lata recovered from the thigh is laid under the separated portion of the trapezius muscle; then another portion of fascia is used to cover it; and the continuation of this fascial sheath, used as tendon of insertion, is led through the deltoid muscle to the point of insertion of the latter. We are not certain that under this condition the portion of the trapezius will function independently.

The method of Ober consists in detaching the origin of the pectoralis major from the thorax, freeing it over the shoulder, where it is sutured to the spine of the scapula with the arm held in abduction. Another method by the same author uses the short head of the biceps and the long head of the triceps as abductors by transferring the tendons of origin of these muscles to the acromion.

While either of these methods may give some definite improvement in the abduction of the arm, on the whole we find that the tendon transplantations for the paralyzed deltoid are rather unreliable.

B. Tendon Transplantation for Loss of Supination at the Elbow. Any existing pronation contracture must be corrected. This can be done readily by splints, or by operation upon the pronator radii teres or quadratus if necessary.

Tendon transplantation for the paralysis of the supinators is indicated in infantile paralysis, in paralysis of the musculospiral nerve, in the pronation contracture of spastic paralysis, or ischemic paralysis, provided that the contracture itself has been previously overcome so that passive

supination is possible before the operation is undertaken.

The method of the writer is as follows:

The plan is transplantation of the flexor carpi ulnaris dorsally to the lower end of the radius.

1. A long volar incision is made along the lower half of the flexor carpi ulnaris, which muscle is exposed, dissected, and severed at its insertion to the pisiform bone.

2. A second, shorter incision is made on the dorsal surface toward the lower end of the radius, between the extensor indicis tendon and the long extensor tendon of the thumb. The lower end of the radius is then exposed.

3. With a long obstetrical forceps a subcutaneous tunnel is made obliquely from the dorsal incision over the dorsum of the forearm, to come out on the volar side at the upper pole of the volar incision.

The flexor carpi ulnaris is now drawn from its point of origin obliquely over the dorsum of the forearm to the lower end of the radius.

4. Then a tunnel is drilled in to the lower end of the radius and the flexor carpi ulnaris tendon is made to enter into the tunnel from the dorsal side so as to come out at the volar end of the tunnel. It is then reflected back and sutured to itself. In this manner the action of the flexor carpi ulnaris is reversed, and it acts now as an active supinator. We prefer this method to Tubby's procedure in which the pronator radii teres and the flexor carpi radialis are both led through the interosseous space dorsally and anchored to the radius.

Following the operation, the hand, forearm and elbow are placed in a cast with the wrist in slight dorsiflexion, the forearm in full supination, and the elbow flexed at right angle. After three weeks the cast is removed and substituted by a splint of the same length and position, and at the same time the after-treatment is begun. This consists in gentle massage and active movements. The splint is worn for a period of two to three months, being removed at least twice a day for treatment and exercises. (Fig. 1.)

*Statistics.** Twelve cases reported. Under the functional classification there were seven good results, one fair, and four poor. Of the four poor results, 2 may be attributed to too much surgery. One result was very good, with supination possible to a range of 80 degrees from mid-position, and pronation possible to 90 degrees from mid-position. In this case there was ability to supinate against resistance.

The correction of the deformity was good in seven cases and fair in five cases. The result was considered good when the transplant functioned actively through a useful arc, with at least 40 degrees of pro- and supinatory motion. The result was fair with a range of motion of between 20 and 40 degrees through a useful arc, and poor when there were less than 20 degrees of motion. Length of follow-up averaged 3.6 years.

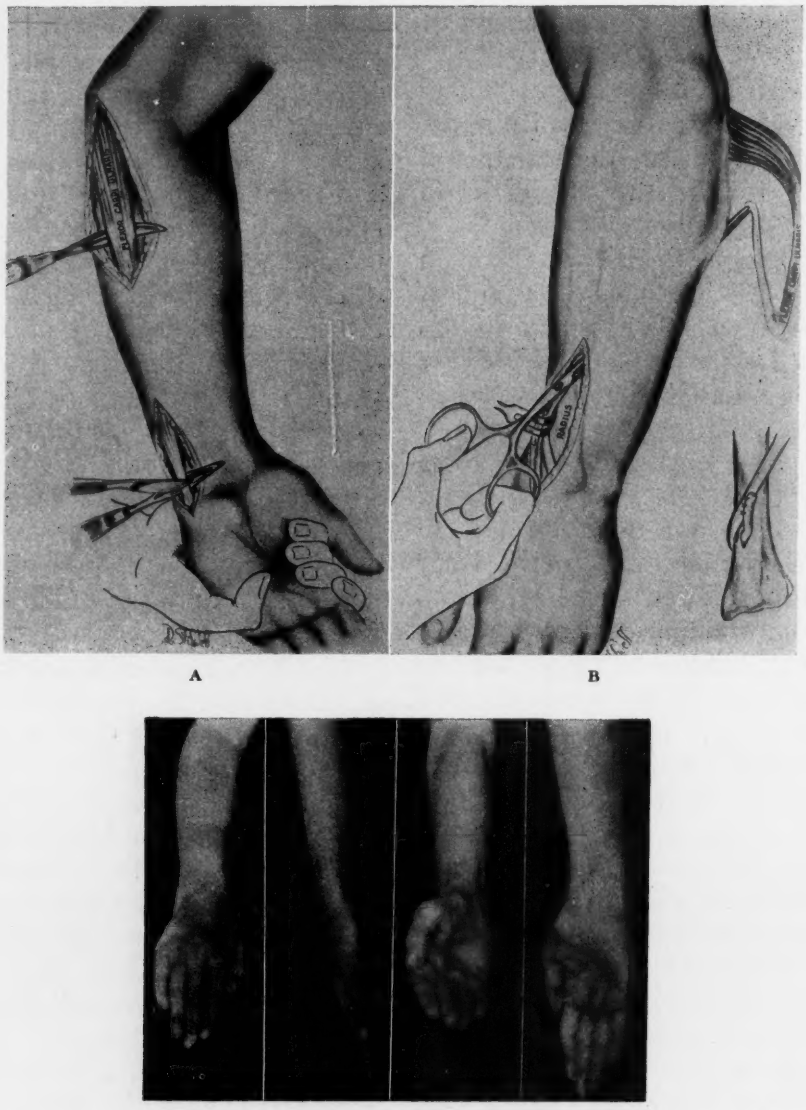
C. Loss of Flexion at the Elbow. This loss of flexion may be due to infantile paralysis, peripheral nerve lesion, or traumatic loss of the flexor muscles.

The principal flexor muscles at the elbow are the biceps, the brachialis anticus, and the brachioradialis. When these three muscles are gone, there remains only the group of the extensors of the wrist, the extensor carpi radialis longior and brevior, coming from the external epicondyle and the external epicondylar ridge, and the flexor group which arises from the internal epicondyle and the internal epicondylar ridge. While all these muscles have a flexory component acting upon the elbow joint, yet, because of the proximity of the muscle axis to the axis of the elbow their rotation moment is so small as to be negligible, and these muscles cannot to any satisfactory degree substitute for the loss of the principal flexors of the elbow joint.

In this situation there are only two practical plans: either to transplant the triceps

* Compiled by Dr. A. W. Ciani, S.U.I., covering a period from January 1, 1926 to April 30, 1938 (Department of Orthopedic Surgery.)

to substitute for the paralyzed flexors, or to rearrange the origin of the flexors of the wrist about the elbow in such a fashion that already mentioned principle of the integrity of the muscle unit and, therefore, physiologically not feasible.



A B C D E F

Fig. 1. Supination of the hand made possible by the transplant of the flexor carpi ulnaris to the distal end of the radius.

they develop a stronger moment of flexion in this joint.

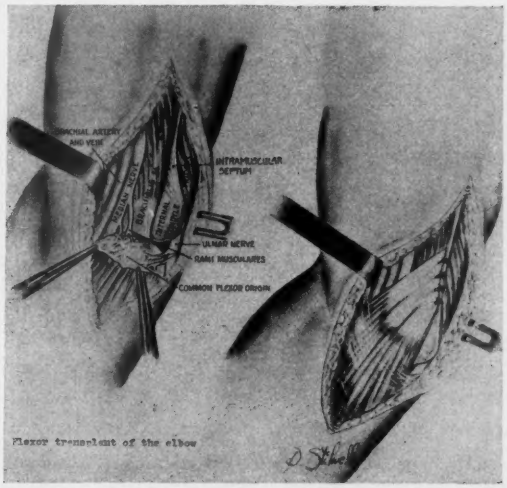
1. The transplantation of the triceps muscle, although it has given occasional results, cannot be generally recommended, first, because of anatomic difficulties, and, second, because the loss of the normal function of the triceps is too great a sacrifice. On the other hand, the splitting of the triceps in an anterior and posterior half with opposing action is a violation of the

In this technique the common tendon of the triceps is separated downward and the dissected portion is transposed to the flexor side of the elbow. Physiologically, of course, it is better to transpose the entire muscle forward.

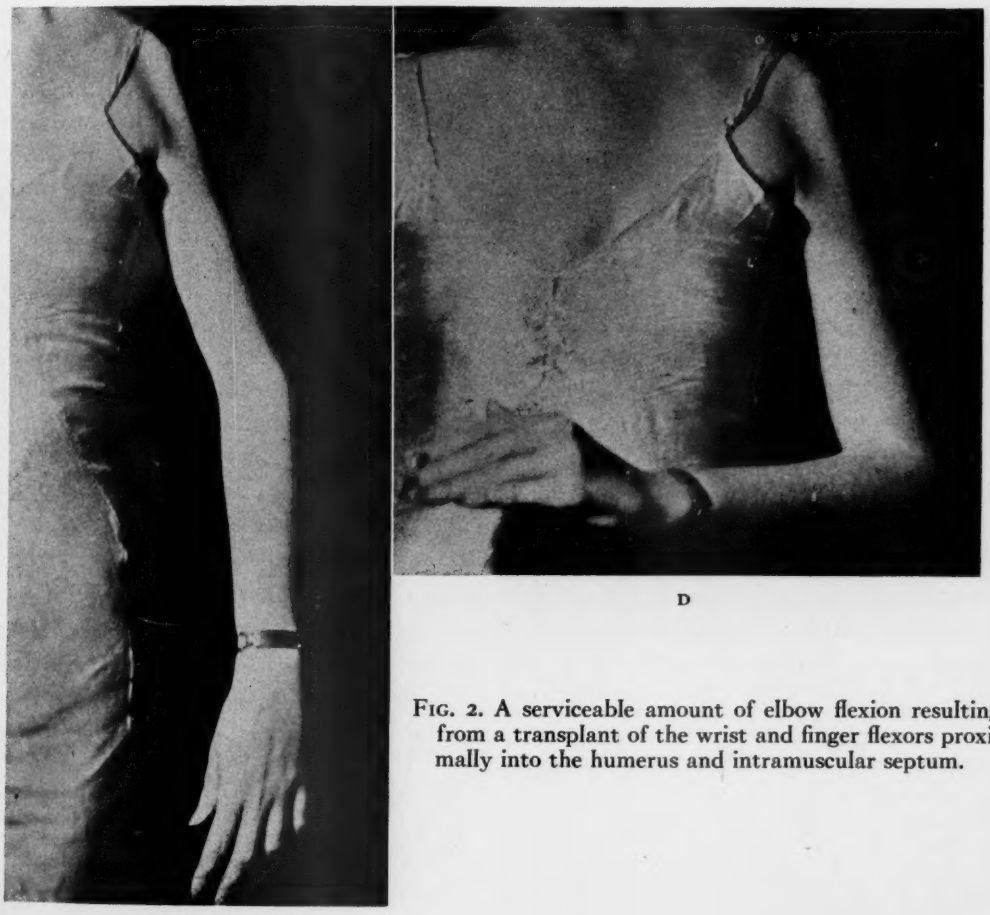
2. A method which has given us very much greater satisfaction and does not entail any sacrifice of muscle is the one used by the writer for about twenty years.

Operative plan: Transposition of the common origin of the flexors from the internal epicondyle to a higher level of the humerus; the preservation of the muscle power of the flexors of wrist and fingers is a necessary prerequisite.

Technique. 1. Incision on the inner side of the humerus, 3 inches above the internal epicondyle, downward, between the brachialis anticus and the biceps muscle, to the internal epicondyle, then forward and obliquely downward in the direction of the



A B



C D

FIG. 2. A serviceable amount of elbow flexion resulting from a transplant of the wrist and finger flexors proximally into the humerus and intramuscular septum.

pronator radii teres, following the radial border of this muscle.

2. After dissection of fat and fascia the ulnar nerve is located, isolated, and carefully drawn backward.

3. The origin of the flexor muscles of the forearm at the internal epicondyle is carefully defined and dissected out, and the muscles are detached from the bone close to the periosteum in one single mass. This mass consists of the superficial head of the pronator radii teres, flexor carpi radialis, the palmaris longus, and the flexor carpi ulnaris. It is possible to strip these muscles down as far as 1½ inches from the internal condyle, at which point the median nerve is seen to send its branches into the muscles.

4. The muscle flap so obtained is now free enough so it can be lifted up and transposed upward, 2 inches above the condyle, into the humerus. For this purpose, the intramuscular septum between triceps and brachialis anticus is followed until the external epicondylar ridge of the humerus is felt, and the humerus is then carefully dissected subperiosteally, and two drill holes from front backward are placed in the humerus about at the level at which the muscle flap is to be placed. Chromic catgut is passed through the drill hole and through the edge of the muscle flap, and the muscle flap is anchored firmly to the humerus. At this point the elbow will be found in acute flexion and it must be held in supination. In this position the arm is placed in a cast.

This cast must be changed in not more than three weeks in order to lessen the flexion of the elbow gradually, and it is then supplanted by an adjustable splint which allows the gradual diminishing of the flexion position. The after-treatment begins with the removal of the cast and consists in active motion, careful massage and muscle training.

It is essential for the success of this operation that the flexor muscles of the wrist show good or normal strength. Because the operation is likely to accentuate an existing pronation tendency, this must be checked by appropriate splinting, and any pronation contracture must have been previously corrected. The power gained by this operation for flexion of the elbow is only moderate but patients are able to carry light objects to the mouth.

If the operation is combined with the arthrodesis of the shoulder, however, as in cases with combined shoulder and elbow paralysis, the advantage of the operation becomes much more obvious. The arm can now be raised to the horizontal position and in this position, since there is no forearm weight to be carried, the flexion of the elbow is very much easier. Our newer statistics on the results of these flexor plasties of the elbow, involving 29 of these operations, give a total of 79.8 per cent good results, 6.8 per cent fair results, and 13.4 per cent poor results; the good results being those in which there is at least 60 degrees of active motion through a useful arc, so that the patient can get the hand to the mouth and extend the arm to at least 120 degrees, and has no pronation contracture.

The failures occur usually in cases in which the flexors of the wrist and fingers are too weak, that is, too severely paralyzed to warrant the transplantation, which was the case in three of our patients; or, as has occurred in one case, the transplanted muscles may pull loose from the new attachment. Here a second operation was necessary, and this gave an excellent result. With the technique of drill-hole anchorage, such an occurrence is not likely to happen. (Fig. 2.)

D. The Flail Wrist or Drop Wrist. The paralytic wrist drop may be due to musculospiral palsy, to infantile paralysis, to ischemic contracture, or to spastic paralysis.

The previously existing contracture must be corrected, and very often this is possible by conservative means. In exceptional cases the resistance of the flexors is too great for correction by passive stretching and the flexors of the wrist must be lengthened to restore normal position. Wherever upon the correction of the flexion contrac-

ture a spontaneous return of the power of the extensors cannot be expected, then tendon transference of the flexors to the extensors is indicated. What type of operation is to be performed depends largely upon whether or not sufficient muscle material is available to give both stability and mobility to wrist and fingers. The muscles available for transplantation must not only satisfy the static and dynamic needs of the wrist and provide extension of the fingers, but also, if possible, abduction and extension of the thumb.

For such a purpose one needs at least three good and strong individual flexor muscles. In isolated paralysis, such as in the musculospiral or in its branches, it is possible to requisition three good flexor muscles; but in infantile paralysis very often such muscle material is not available.

The Special Technique. (*a*) Sufficient material is available.

Substitution by the method of Robert Jones. The operative plan is the transposition of the flexor carpi radialis, of the pronator radii teres, and the flexor carpi ulnaris to the extensors of wrist and fingers.

We use the palmaris longus instead of the pronator teres.

Technique. 1. From a long volar incision the flexor carpi radialis, the palmaris longus, and flexor carpi ulnaris are isolated as far distally as possible. From a smaller, dorsal incision over wrist and lower forearm the compartments for the common extensors, the long extensor of the thumb, and the abductor longus and extensor brevis pollicis are opened and the tendon exposed.

2. The flexor carpi radialis is then swung around the radial border to be united and fastened to the extensor pollicis longus.

3. The palmaris longus is swung around the radial border to be united to the abductor pollicis longus and extensor pollicis brevis.

4. The flexor carpi ulnaris is swung around the ulnar border, led through the compartment of the common extensors, and split up in several slips which are united individually to the four extensor tendons of the fingers.

The after-treatment requires complete plaster immobilization with wrist and metacarpophalangeal joints in extension position for a period of two weeks. The ends of the fingers must be left out of the cast since the extension of the interphalangeal joints is not a function of the extensors but one of the lumbricales and interossei. Massage and active motion begin early, with the healing of the wound. The cast is removed after two weeks and immediately substituted by a splint holding the fingers in the same position. This splint should be worn for six months. (Fig. 3.)

Our series of cases of tendon transplantations performed for infantile paralysis showed 80 per cent acceptable results. Failures were due to errors in indication and technique, and especially to errors in the after-treatment.

We do not favor the institution of active motion within a few days after operation, but it is advisable to start massage not earlier than the eighth or tenth, preferably the fourteenth day, and then only with the greatest precaution. Active motion may be allowed from the eighth day in the bivalved cast or through a window in the cast.

(*b*) The muscle material available is not sufficient for both dorsiflexion and stabilization of the wrist.

It appears that some stabilizing method must be added, either the ligamentous suspension or tenodesis, or the arthrodesis. Of these two we much prefer the arthrodesis because the tenodesis does not stabilize the wrist but merely suspends it in extension. The arthrodesis, however, stabilizes the wrist definitely in the desired position of slight extension. We found that this combination of arthrodesis with tendon transplantation gives fairly satisfactory results, although not as good, of course, as in those cases in which sufficient muscle material is available for both motion and stabilization.

E. The Thenar Palsy or the So-Called Flat Thumb. The paralysis of the thenar

muscles arises from infantile paralysis, from peripheral paralysis, from traumatic separation of the ulnar nerve, or from an ischemic contracture. The paralysis of the thenar muscles incapacitates the hand to a considerable degree as the most primitive movements of the hand depend upon opposition of the thumb. This opposition may be substituted by the adductors of the thumb and the long muscles, but it is as a rule impossible for the thumb to meet the tip of the index or middle finger.

We must distinguish between the pure opposition of the thumb in which position the thumb is simply opposed to the finger at a certain distance; and the adduction-opposition of the thumb in which position the thumb is not only opposed but is also adducted and pronated against the finger.

The former position requires the action of the abductors of the thumb, particularly the abductor longus and extensor brevis, in addition to opponens action, and may be considered to be the first part of the entire

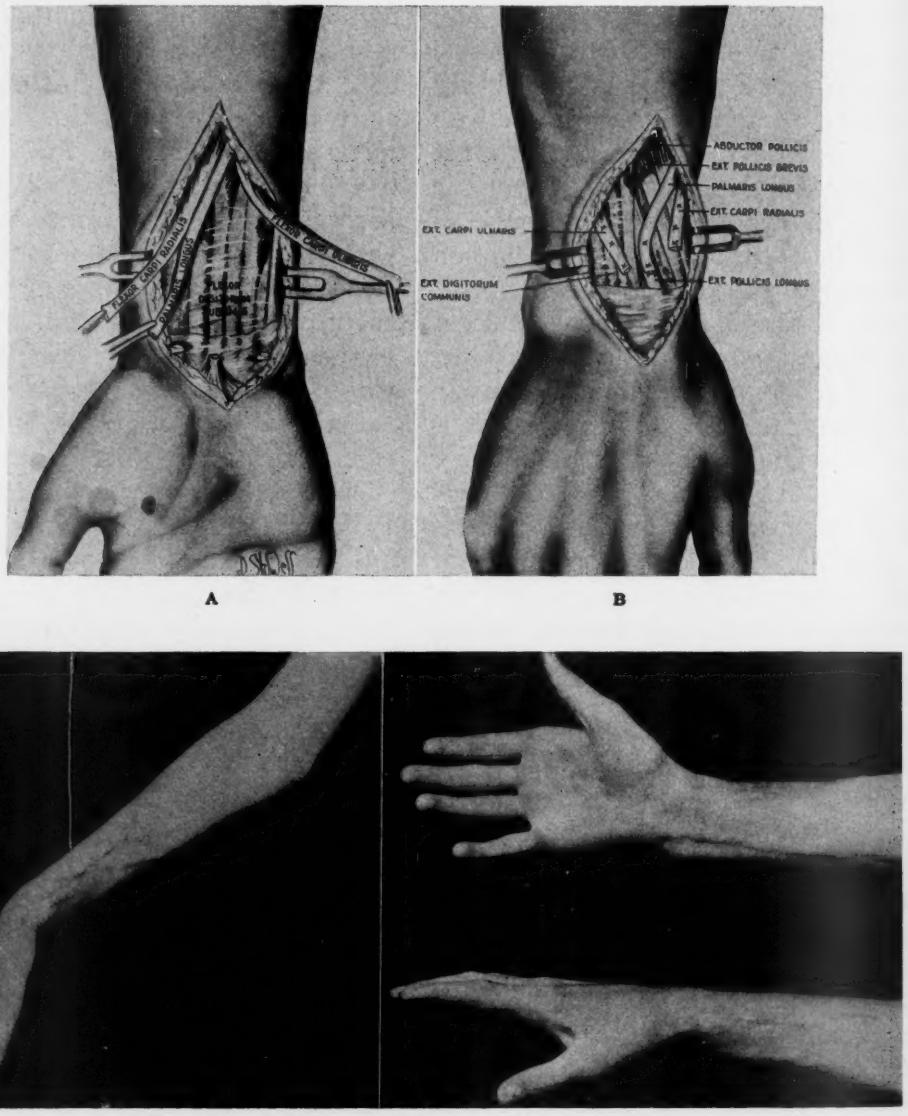


Fig. 3. A shot-gun wound involving the extensors of the fingers and wrist; also abductor of the thumb. The flexor carpi radialis, ulnaris, and palmaris longus were transplanted to the extensors of the fingers, wrist, and abductor of the thumb.

circumductory movement of the thumb. In order to bring the thumb into full circumduction there must follow upon the former movement also the adduction and flexion in the metacarpophalangeal joint (short flexor action).

All these motions are eliminated in the thenar palsy and must be substituted.

In the method used by the author this substitution is carried out by a part of the long flexor of the thumb. This is split and the radial half of it is anchored to the base of the basal phalanx. This second tendon attachment has the effect of both an adductor and an opponent, and of a flexor of the metacarpophalangeal joint, and it substitutes all the elements of complete abduction-opposition which had been lost by the thenar palsy.

The technique is as follows:

1. An incision is made on the radial side of the thumb from the middle of the end-phalanx down to the middle of the thenar, so as to avoid the motor branches entering from the median nerve.

2. The long flexor of the thumb is now exposed through this incision, its sheath is excised, the edges of the sheath being secured by fine forceps.

3. The tendon is lifted out of its sheath and split longitudinally the full length of the incision. The outer or radial half of the tendon is severed at the distal end of the split and reflected upward and the sheath of the long flexor tendon is reunited over the remaining ulnar half.

4. The radial tendon flap is now carried around through a tunnel made in the soft parts and led out through a point at the base of the basal phalanx well upon its dorsoulnar side.

5. A short incision is made at this point through which the tendon is led out. The periosteum of the base of the basal phalanx is exposed and a tunnel is made through the base through which the tendon half is passed, reflected and fastened to itself. In this manner it encircles the proximal phalanx of the thumb.

6. The dressing is applied as follows: The thumb must be held in the position of opposition and adduction and the end-phalanx of the thumb must be flexed.

This position is of importance for function. Flexion of the end-phalanx is necessary in order to relax the half of the long flexor of the thumb which has remained in situ. Unless this is done, the contraction of the common tendon of the long flexor of the thumb will produce a flexion of the end-phalanx before the thumb is circumducted, making the opposition of the thumb to the tips of the fingers impossible. The procedure simply provides a second attachment for the flexor of the thumb so that when this muscle contracts the tendon flap brought around the thumb causes it to swing around in opposition with the trapezium as a pivot. The thumb is then able to approach the little finger and carry out gripping motions.

Two points are essential: (1) That the tendon of the flexor pollicis longus is split long enough, from the base of the end-phalanx down to the middle of the metacarpal, in order to get a long enough flap which can be carried around the base of the basal phalanx in oblique direction, corresponding to the direction of the opponens pollicis. (2) The other point, already mentioned, is that the thumb be dressed in opposition with the end-phalanx flexed.

The principal condition for the success of the operation is that the flexor pollicis longus must be well preserved.

Statistics on the end results of the flexor plasty of the thumb:* Good or excellent results obtained in 72 per cent, fair results in 5.5 per cent, and failures in 22 per cent.

The causes of failures were inadequate strength of the flexor pollicis longus, failure of proper anchorage, and deficient after-treatment, that is, failure to secure the thumb in opposition with the end-phalanx flexed. These factors are avoidable and

* Compiled by Dr. J. B. Davis, S.U.I., Department of Orthopedic Surgery.

there is no reason why this operation should not give a uniformly good result. (Fig. 4.)

The method of Bunnell is based upon to the pisiform bone. The operative plan is to take one of the flexor tendons of the forearm which is run through a pulley

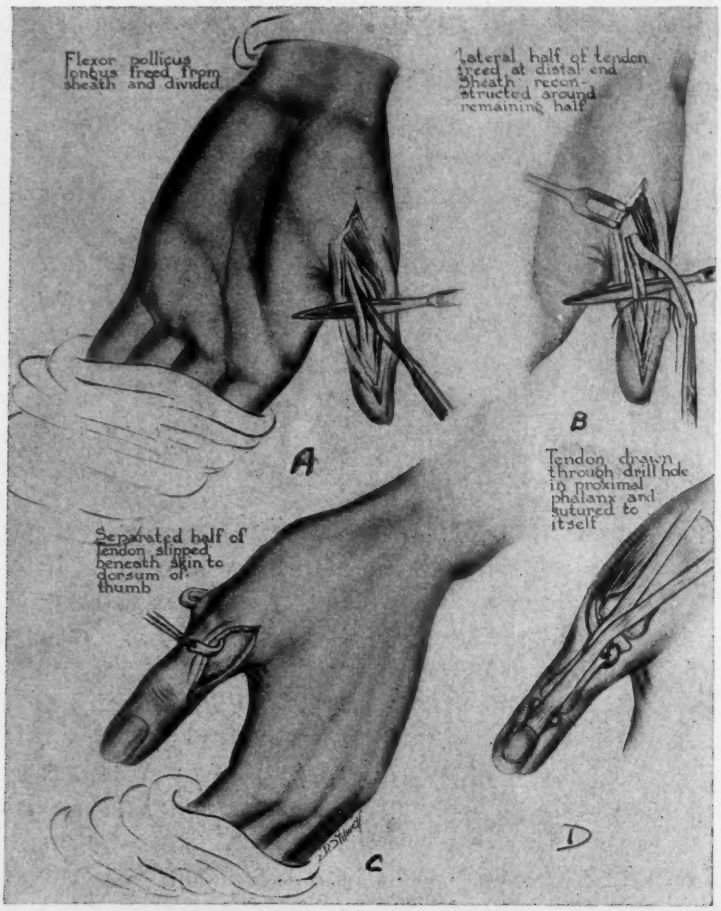

Flexor pollicus longus freed from sheath and divided
A
Lateral half of tendon freed at distal end. Sheath reconstructed around remaining half
B
Separated half of tendon slipped beneath skin to dorsum of thumb
C
Tendon drawn through drill hole in proximal phalanx and sutured to itself
D

FIG. 4. Flexorplasty of the thumb. A and B, range of motion possible in the thumb before operation. C, opponent action carried out by the transplanted portion of the flexor pollicis longus.

the conception that to reconstruct the opposition the pull must be in line from back of the distal end of the first phalanx at the pisiform bone. From there the tendon or its prolongation by a free graft is passed subcutaneously to the dorsum of the

distal end of the metacarpal of the thumb into a drill hole through which the tendon end is looped and sutured to the tendon. Bunnell uses the flexor carpi ulnaris for the muscle and the flexor palmaris longus partly for the pulley and partly for the prolongation of the flexor carpi ulnaris, so that it may reach the point of implantation at the base of the distal end of the metacarpal of the thumb.

The method of Ney makes use of the action of the palmaris longus. The extensor pollicis brevis is severed above the level of the volar carpal ligament and its peripheral end is led volarly through a subcutaneous tunnel under the volar carpal ligament, and is then united with the tendon of the palmaris longus.

CONCLUSIONS

On the whole, the field of tendon transplantation in the upper extremity is much wider than it is in the lower, because of the preëminence of the mobilizing function of muscle action over the stabilizing. This does not mean, however, that the stabilizing component is negligible. On the contrary, in transferring the wrist flexors to the extensors of the fingers, for instance, we must definitely count upon the stabilizing effect of these muscles on the wrist, because without it movement of the fingers would be weak and uncertain. It merely means that in the upper extremity the requirements of stability are not nearly so exacting as they are in the weight-bearing joints. The second point in favor of the upper extremity is its greater adaptability to new function; that is, the muscles can reverse or change their original function in a much broader sense than they can in the lower extremity.

On the other hand, because of these conditions, the after-treatment of the tendon transplantation operations in the upper extremity is undoubtedly more complicated and more intricate than it is in the lower. I should like to emphasize in this respect two points:

1. Do not start any kind of motion in tendon transplantation until at least two weeks after the operation, and then only active motion in the gentlest possible manner.

2. When splints are applied it must be remembered that in the upper extremity postural contractures occur very much sooner and are very much harder to combat than in the lower. It is our custom, therefore, not to leave the same splint on continuously, but to alternate with others which hold the fingers in a reversed position. For instance, splints holding the fingers in complete extension, as employed in transplantation of flexors to extensors, should never be left on for an entire day but should be alternated with others which allow slight flexion of the mid- and end-phalangeal joints. Otherwise, capsular contracture in these articulations will produce extension deformities which are extremely hard to overcome.

It must be realized how delicate the balance is between extensor and flexor groups and that such balance can only be maintained by the action of the intrinsic muscles of the hand. Consequently, in the absence of these muscles there is a constant tendency to develop contractures and one must forever be on guard against them.

The outlook for tendon transplantations in the upper extremity is quite hopeful and the field is large. The indications must be made very judiciously and only upon careful analysis of the muscle dynamic situation.

Every technical detail must be carried out with even greater care than in the lower extremities because interference with free function of the tendon occurs so easily.

Finally, the end result of the operation stands and falls with the after-treatment. Many cases look very promising after the cast is first removed, but frequently the result is lost because of the inadequate or improper postoperative care.

TENOTOMY, ITS INDICATIONS AND TECHNIQUE*

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TENOTOMY is the section of a tendon for the correction of a deformity and was first performed in the early part of the seventeenth century by Minnius, Roonhuysen and others, and again in 1784 by Thilenius, Lorenz and Sartorius. These earlier operations were all done by the open method and are recorded as quite successful. However, it was early recognized that the infection which followed the open method (commonly ascribed to the effects of exposure to air), tended greatly to delay the recovery of the case, and, by the resultant scarring, to complicate the final results in many instances. In 1816, Delpech performed the first successful subcutaneous tenotomy on a case of clubfoot, but the operation did not become popular until Stromeyer, in 1831, showed that it could be done almost with impunity. This period marks the real beginning of tenotomies in orthopedic work. To William Little of London, belongs the credit of its success in England. He was afflicted with double congenital clubfeet and visited Stromeyer who, by cutting both heel tendons, secured sufficient correction to permit Mr. Little to walk upon the soles of his feet (though the varus deformity persisted). The relief obtained by Little made him an ardent advocate and follower of the procedure and gradually the opposition of English surgeons was overcome and the operation became of wide and general use.[1]

The indications for the operation are malformations due to muscle contractions or shortenings and any muscle dysfunction which, if permitted to persist, will result in shortening and cause either temporary or permanent deformity in the actuated part. Also, in cases of muscle imbalance, whether from lesions in the central nerve system or from local spasm of persistent type, tenotomy is a most valuable procedure in the effort to restore balance.

The operation is naturally divided into two methods, the open and the closed (or subcutaneous) and each may be said to have its own particular indications. However, the anatomic knowledge and surgical skill of the operator commonly prove the determining factors in the selection of the method to be used. The open method is chiefly employed in those areas in which there is danger of injury to important adjacent nerves, blood vessels or other structures (such as at the base of the neck for wry neck, the folds of the axilla, the adductors of the thigh and the internal and external hamstrings at the knee) while in superficial areas and structures, with prominence of the tendon, the subcutaneous is the method commonly employed. The comparison of the advantages of the two procedures is shown in the following table:

Open	Closed
1. No danger of injury to neighboring parts.	1. Danger in certain areas.
2. Accuracy in lengthening.	2. Less so.
3. Each step of operation visible.	3. Invisible.
4. Certainty of apposition of tendon ends.	4. Uncertainty.
5. In tendons having a synovial sheath, this method must be used.	5. Contraindicated unless the sheath is very short (toes, etc.).

[1] The facts regarding William Little were given to the writer by the late E. Muirhead Little of London, who was internationally known for his work in orthopedic surgery.

* From the Orthopedic Department of the Jefferson Medical College.

The disadvantages may be listed as follows:

Open	Closed
1. Greater danger of infection.	1. No danger.
2. Length of time necessary for performing the operation.	2. Quickly done.
3. Large amount of scar tissue.	3. Practically none.
4. Subsequent adhesions about the tendons frequently interfering with the after-excursion of the tendon.	4. None.
5. Scar in the skin may be unsightly (as in the neck) or may be irritated by the clothing (as above the heel).	5. Absent.
6. In the event of reoperation, greater difficulty is encountered.	6. Practically absent.

In the hands of the experienced surgeon, the closed procedure has practically superseded the open and the disadvantages are seen to be almost negligible. The selection of the proper knife for the subcutaneous operation is of importance. The type commonly offered for sale by the instrument dealers is entirely too large and in using it, much greater damage is done to surrounding structures than is necessary or desirable. The cutting blade should not be more than ½ to ⅝ inch long, need not be more than 1/16 inch wide, and must be thick enough to avoid danger of breaking. One's equipment should include several sharp-pointed and several blunt blades. The shank between the blade and the handle should vary from 1 to 2½ inches in length. The handles may be square or flat, but should have a dull or rough finish rather than a smooth plating. This allows a firmer grasp of the knife and guards against slipping. Another essential factor is that the blade shall be sharp. If it is sharp and the tendon is held tense, very slight contact of the knife with the tendon will sever it, while if dull, greater effort will be needed and the blade may be broken by the pressure necessary to cut the tendon.

The type of open operation which has been used for nearly fifty years is that described and published simultaneously by Dr. Keen of Philadelphia and Mr. Anderson of Ireland, originally called the Anderson-Keen method, and now known as the "Z" method. It consists in (1) the exposure of the tendon by a sufficient incision through the skin directly over or by the side of the tendon and free separation of the tendon from its tissue sheath. (2) The tendon is then split either anteroposteriorly or laterally for the desired distance (2 or 3 inches); (3) one-half is cut off at one end and the other half at the other end. Then, (4) by pulling upon the distal or attached end, the two parts are slipped past each other for the desired distance and (5) one or two sutures are placed to hold the tendon ends in lateral apposition. (6) The skin incision is evenly closed and a splint of plaster or other firm material is applied to fix the part in the corrected position until firm union occurs.

This same lengthening, in a tendon without a synovial sheath, can be accomplished subcutaneously by putting the tendon in tension, (7) insertion of a sharp-pointed tenotome through the skin at the upper end of the tendon and piercing it near the center. The tenotome is then turned at a right angle and one-half of the tendon is severed. The knife is withdrawn and reinserted 1 or 1½ inches below and the other half of the tendon is severed. Firm corrective pressure is made upon the distal part of the tendon attachment and the fibers of the tendon (which are parallel) easily slip past each other and allow the required amount of lengthening to be accomplished. (8) This procedure is extremely simple and most satisfactory in cases of superficial tendons. If, however, the tendon fibers are twisted (as sometimes occurs in the Achilles tendon) the knife should be reinserted at one or the other end, a few more fibers severed and full correction secured.

Where section of the tendon is desired and preservation of its fibrous continuity is not essential, the tendon is put under tension and a sharp-pointed tenotome is inserted through the skin, preferably at the

side of the tendon. The blade of the knife is pushed forward with the flat side next to the tendon, either on the upper or on the under surface as seems desirable to the operator. The knife is turned with the cutting edge against the tendon and with a sawing motion the tendon is severed. By the use of extension-pressure, the ends are separated sufficiently to permit correction of the deformity. The wound is covered with a small gauze dressing and the fixative agent or apparatus is applied at once to maintain correction.

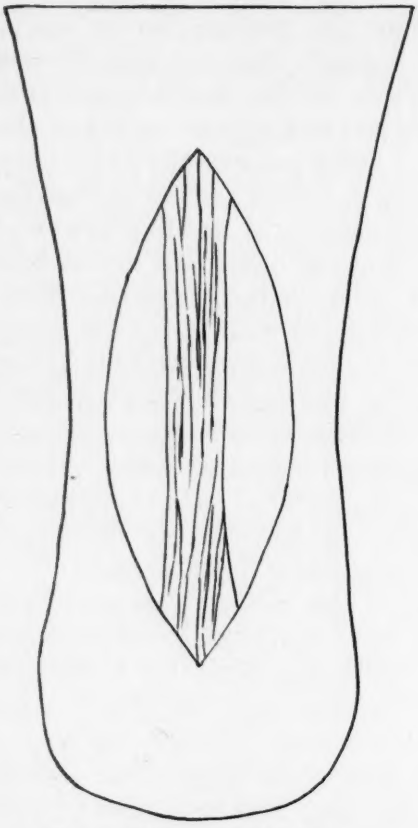

Fig. 1. Exposure of tendon.

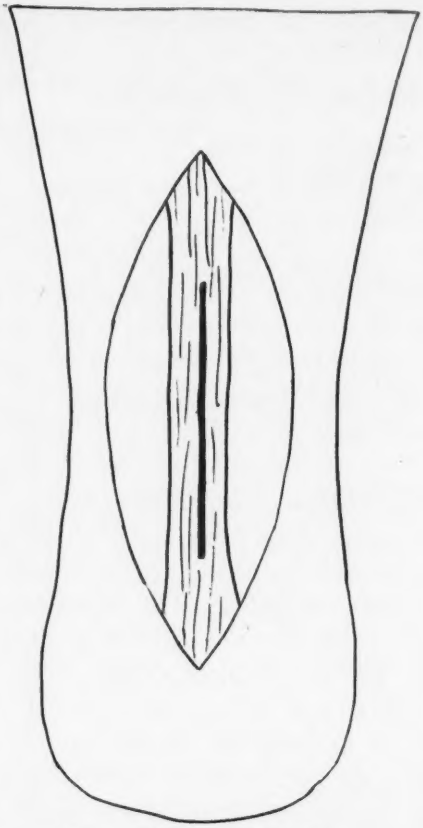

Fig. 2. Splitting of tendon.

If possible, complete rather than partial lengthening of the tendon should be secured at the time of operation, though the changes in the surrounding tissues and nearby bones and joints and the tension upon neighboring vessels and nerves, may render full correction either inadvisable or impossible. When the resistance of the surrounding tissues (including the bony structures) is pronounced, attempts to secure and maintain full correction may result in pressure sores which may, in turn, vitiate the ultimate results of the operation. In such cases, it is much better to complete the correction by stages, increasing the pressure every five or six days according to the reaction of the local tissues until the desired result is obtained.

When tendon lengthening was first employed, there was considerable diversity of opinion regarding what happened to the tendon ends and how great were the dangers of nonunion. Extensive experiments upon animals were early made by Paget (Lectures on Surgical Pathology, London, 1853) and since verified by many others, which demonstrated that union occurred by the pouring out of a lymph-like fluid which became organized and formed a continuous structure, almost indistinguishable from tendon tissue, between the tendon ends. Nonunion of a tendon without a synovial sheath occurs but rarely and

full correction of the deformity should be accomplished at once if possible.

Healing of the tendon is usually complete in three weeks and after this time, a gradual return of function is permitted and encouraged. This gradual use of the part (where the tendon performs an important function, as in the tendo Achillis) stimulates healing and a firmer organization of the reparative tissue though if too free use is allowed, the cut area will develop greater thickening from proliferation of surrounding connective tissue cells than if function is resumed more slowly. The amount of function permitted will depend greatly upon the site of the operation and the importance of the structures severed. In cases of torticollis, massage of the sternocleidomastoid muscle should be begun in two or three days so as to insure full muscle lengthening and thorough stretching of the surrounding fasciae. The same procedure is followed in section of the muscles in the axillary region and of the adductors of the thigh as, in these areas, scar tissue forms quickly and, unless thorough stretching is maintained, recontraction will take place promptly. In the case of tendons having synovial sheaths, motion should not be attempted for from two to three weeks as firm union of the tendon ends is essential to the after function of the part and too early efforts at function may separate the ends and prevent healing. A similar precaution applies to the tendo Achillis because of the tremendous strain put upon this part in the function of walking and subsequent danger of overstretching or nonunion.

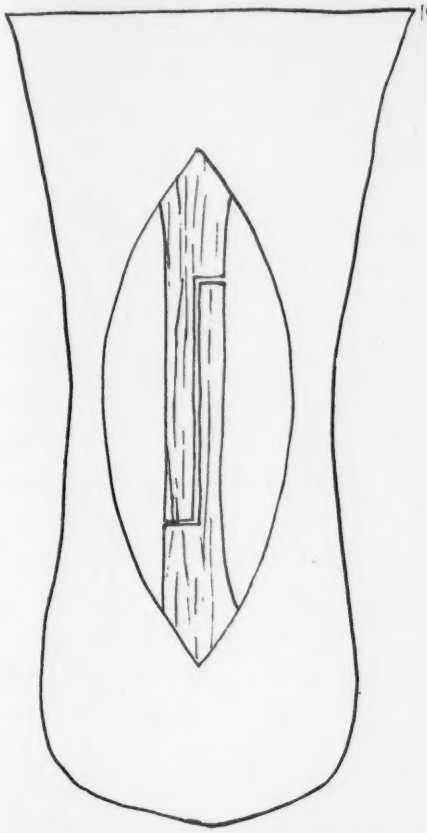

Fig. 3. Cutting of opposite ends.

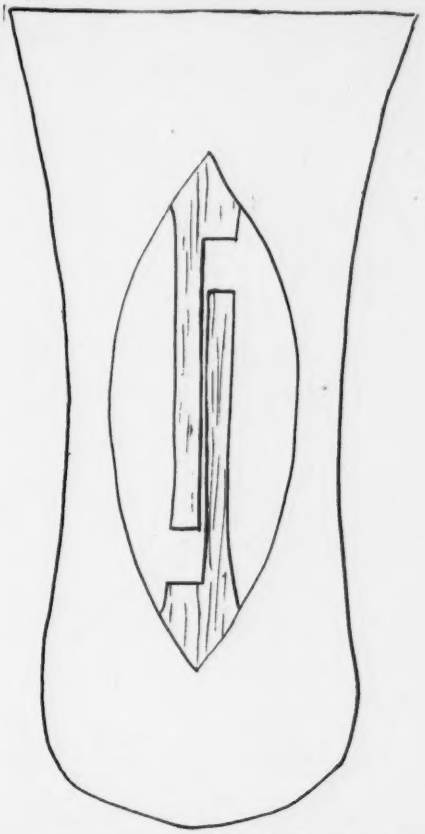

Fig. 4. Lengthening by extension pressure.

The surgery of the synovial sheathed tendons is a specialty in itself and requires great skill and meticulous care in its performance and follow-up. Unless the surgeon is skilled in dealing with these tissues, he should be very loath to undertake such an operation, and even in the correction of

congenital or acquired deformities due to muscle shortening, one should realize the exceeding importance of the after-care and

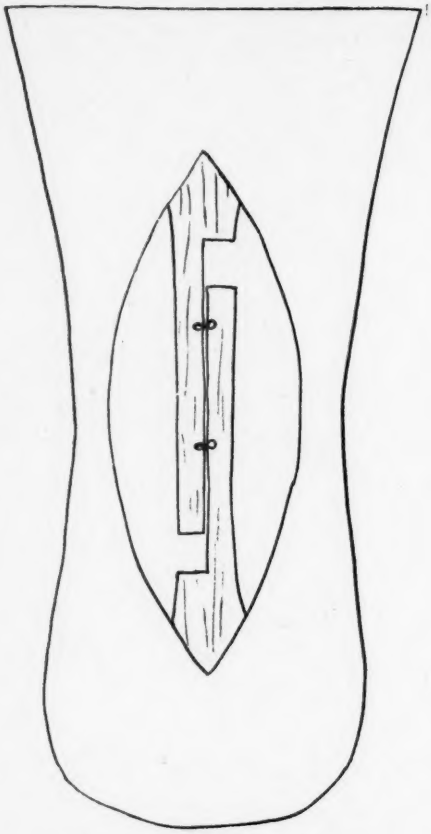

Fig. 5. Suturing the ends.

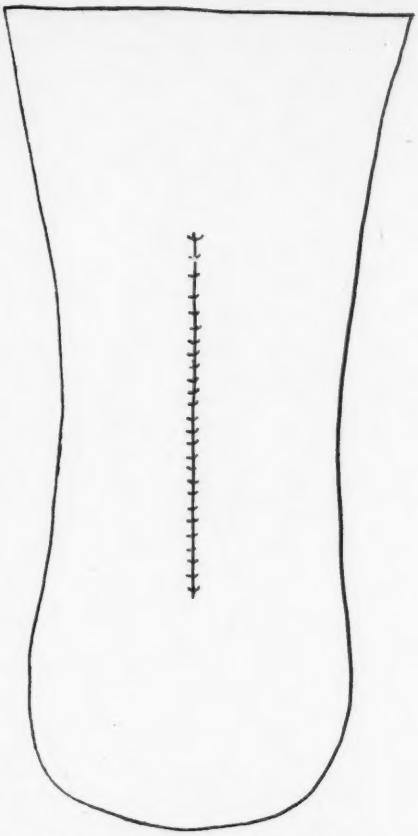

Fig. 6. Closure of skin incision.

treatment because of the danger of return of the deformity from contraction in ensuing scar tissue or from the persistence of the influences peculiar to the disease or deformity and its tendency to resume the primary malposition.

In cases of spastic paralysis of the extremities, where there is marked imbalance from the greater pull of one muscle group against another, combined with profound disturbance of muscle control, the best functional results can be obtained by weakening the stronger ones by means of tenotomies. Neurectomy has been tried and, in general, has been found wanting in its results. Furthermore, the loss of control from section of the motor nerves is permanent and as time passes, the opposing muscles may become overacting and cause deformity in the opposite direction, and in such cases corrective measures through muscle action are lost. Experience has shown that growth and development oft-times bring about marked improvement in these cases of imbalance, but if there is motor paralysis from neurectomy, there will still be less opportunity to secure balanced control in the muscle structures. The simplicity of subcutaneous tendon section as compared with the severance of nerves (which may require extensive and careful dissection) and the retention of power in the spastic muscles which may in many cases be brought under better control by systematic training, strongly recommends the procedure. Furthermore, if the first effort at restoring better balance by tenotomies is not successful, the operation can be readily repeated and by gradual stages, a more nearly normal balance of the muscles can be obtained. When this is secured, muscle training can be carried out more easily and with much better results.

TECHNIQUE OF SECTION OF SOME OF THE SPECIAL TENDONS

In torticollis, one or both portions of the sternocleidomastoid muscle may be involved, but the method of correction is the same for both conditions. The muscle is put in tension by pulling the arm downward and twisting the head so that the face turns to the affected side and the head to the opposite side. The tenotome is inserted near the posterior edge of the muscle and pushed forward along the upper border of the clavicle. The knife blade is then turned with the cutting edge against the tendon and the tissues are cut freely from the clavicle. The blade is pushed forward as the cutting proceeds, until the entire structure is severed. The fear of the operator is that he may injure the artery, vein or nerve that lie beneath, but if he will recall the thickness of the clavicle and that the muscle lies between the two layers of fascia, the danger of such mishap is avoided. After withdrawal of the knife, the corrective tension is maintained and the index finger is used to tear through any remaining fibers and to push the posterior fascial plane off the clavicle. This requires considerable pressure by the finger end, but if it is persistently applied, a deep groove or sulcus will be felt along the top of and behind the clavicle and correction will be well accomplished.

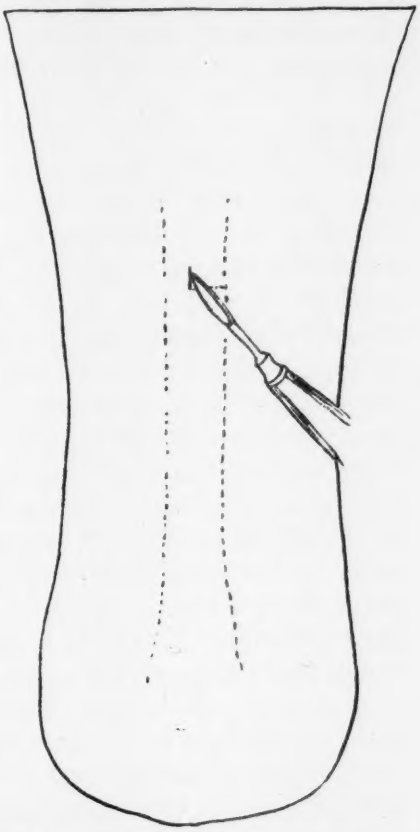

FIG. 7. Piercing the tendon at upper level and cutting off one-half.

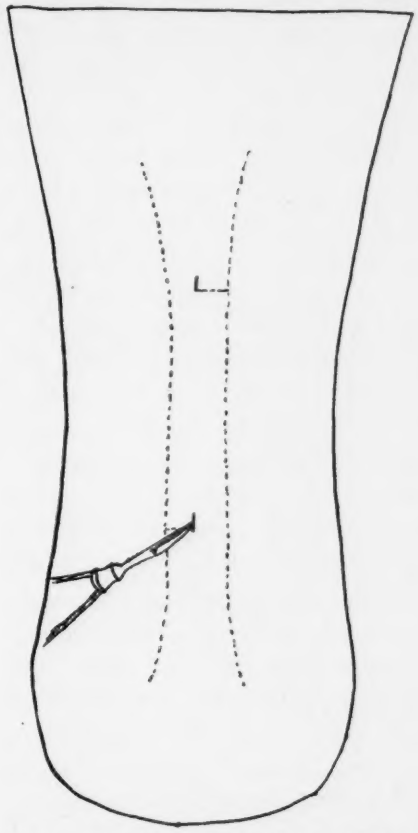

FIG. 8. Section of the other half at lower level.

In cutting the anterior and posterior muscles of the axilla, the arm should be abducted firmly and the tendon attachments to the humerus noted with the finger. The tenotome is then inserted either on the outer or under edge of the tendon and the tendon is freed from the humerus. Further stretching of the arm outward and upward will secure greater separation of the severed parts. This procedure is curative in some cases of recur-

rent dislocation of the shoulder as the head of the humerus may be dislocated downward when the arm is elevated by the

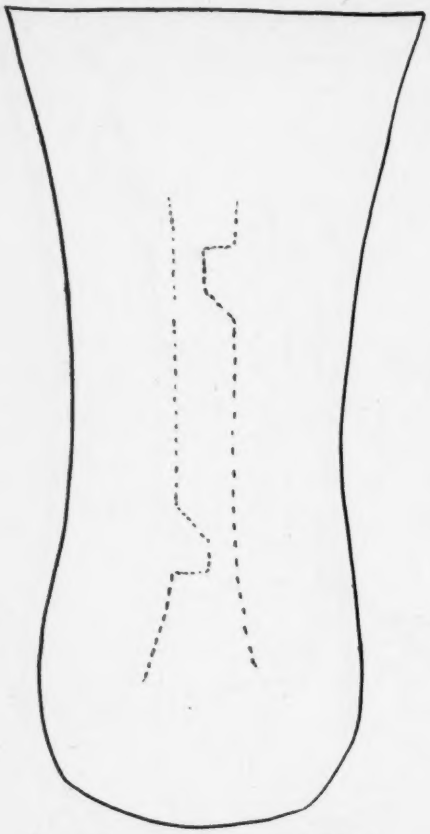

Fig. 9. Lengthening accomplished.

pull of the deltoid and supraspinati muscles (Allis). This procedure is also indicated in some cases of neglected birth palsy in which marked shortening of the pectorals, latissimus and teres muscles occurs.

In marked adduction of the thigh, muscle section is accomplished quite close to the pubis. The tenotome is inserted just over the tense fibers as the leg is strongly abducted. All structures close to the pelvis are severed and then further elongation is secured by kneading the muscles to break through any remaining fibers. By this procedure, there is no danger of injury to the neighboring artery, vein or nerve.

In section of the internal and external hamstrings, the leg should be flexed on the pelvis and the lower leg extended as far as possible. This causes the tendons to stand out prominently. If the knife is inserted along the outer side of the tendons and slight cuts are made, the tendons readily give way. The leg should then be extended completely at the knee and the entire leg forcibly flexed to a right angle with the pelvis. In rare cases it may be necessary to cut the semitendinosus tendon which runs through the center of the popliteal space, but as it is extremely tense and located directly under the skin, its section presents but little danger. These tendons are commonly affected in spastic paralysis and sometimes hinder the patient from walking on the foot-sole and heel. The condition may simulate shortening of the tendo Achillis. If this is present, it must be corrected before the heel tendon is cut. Where toes have become contracted from short shoes and stockings, section of the plantar flexors will allow them to be straightened. The outer toes are the ones most commonly involved, and these tendons can be readily severed if the assistant will hold the foot in dorsal flexion by pressure against the metatarsal heads, thus causing marked plantar flexion of the toes. A long shanked knife is then inserted just in front of the metatarsal joint of the little toe, the point of the toe lifted with the left hand and the plantar tendon easily cut. The knife is pushed further across and the fourth toe tendon severed, then the third toe cut and finally the second one, all through the one skin puncture. After this, a small piece of gauze is placed over the puncture and held in place by adhesive tape. The shoes and stockings are put on and the patient walks out with but a minimum of inconvenience and a maximum of relief.

LESIONS OF THE EPIPHYSES

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GROWTH phenomena are dependent on the undisturbed normal development of the epiphyses.

Knowledge of epiphyseal growth prior to Roentgen's discovery was entirely dependent upon anatomic maceration studies. However, shortly after the epoch-making work of Roentgen, Poland began his remarkable study of epiphyseal development from a radiologic standpoint.

In order to discuss disturbances or lesions of the epiphyses, one must appreciate several facts with reference to them:

1. The epiphyses appear at a definite period.

2. Ossification as a rule proceeds in an orderly manner within the particular epiphysis.

3. There are as a rule a definite number of epiphyses for each of the long bones.

4. Ossification between the epiphysis and the diaphysis occurs at a definite period, under normal conditions.

5. Endocrine disturbances either delay or accelerate ossification within the epiphyses. Premature ossification leads to dwarfism, and delayed ossification may lead to gigantism.

6. Knowledge of the foregoing facts aid one in suggesting the probability of certain endocrine disturbances.

7. Since premature ossification leads to retardation of growth of an extremity, it follows that injuries about the epiphyses should not be operated upon.

8. The *x*-ray cannot be used to make the diagnosis of fractures about the joints in the very young. The epiphyses may be fractured, but on account of their cartilaginous nature the fracture may be missed.

9. A thorough study and knowledge of the appearance of the various joints at all ages from birth to adult life is essential if one would attempt to interpret lesions of the epiphyses. No important subject is so completely ignored by the average physician as the knowledge of the appearance of the epiphyses.

There is one term which I believe should be entirely deleted from medical nomenclature—that term is epiphyseal separation. This is a thought which many observers had even before the days of the *x*-ray: for example, Malgaigne, in 1859, stated: "I rank among fractures these lesions (epiphyseal separations) which some modern authors would consider as distinct from them." In 1866, Hastings Hamilton said that, "Epiphyseal separations we shall not hesitate to classify with fractures and to submit them to the same rules of nomenclature."

For some strange reason surgeons have spoken of epiphyseal separations, apparently considering the epiphysis as something quite apart and not truly united with the shaft. Even though osseous union is not present, the union is cartilaginous; if we continue to hold to the definition of the term fracture as a break in continuity of bone or cartilage, we must of necessity consider all solutions of continuity of or through cartilage as true fractures. It follows that all epiphyseal separations are in reality fractures. If there is any displacement it is truly a fracture with displacement just as a similar fracture through bone would be.

It has become axiomatic to state that we cannot interpret injuries to the epiphyses unless we know what the normal looks like and what evidences of displacement are present after injury. It also becomes increasingly important to realize that in

the extremely young, prior to the period of ossification, the clinical examination, the interpretation of loss of function, and the localization of pain are of greater importance than the *x*-ray, a point to which I have previously referred in a paper on "Clinical Examinations versus the *X*-ray in Children." Anyone who has occasion to observe a great many injuries in the very young, will know how often one sees no radiographic evidence of a fracture line about joints although the clinical evidence of fracture is definite.

I believe that many normal joints are interpreted as epiphyseal separations by those who are not fully conscious of the appearance of the normal. On the other hand, it is important not to accept the absence of *x*-ray findings as excluding fracture and diagnose a so-called contusion or sprain. Both of these diagnoses are made entirely too often and without justification. The term sprain might well be almost deleted from the nomenclature of surgical literature. Careful study of patients who are supposed to have sprains will prove that they have fractures. In order to confirm this statement, one has to examine his patients carefully, insist on having pictures in various planes, and depend largely on clinical diagnosis.

It is urgent for us to remember that the small bony prominences to which ligaments are attached have less tensile strength than the ligaments which are attached to them. Therefore the ligaments will not tear or be injured before the bony prominence is pulled away from the shaft. Observance of this important point will help us to get away from the superstition that a sprained ankle hurts more and longer than a fracture. The pain is doubtless due to the fact that the individual has had a fracture which was unrecognized.

There are certain fundamental facts which become a part of our visual consciousness with reference to the appearance of epiphyses, and these are of vital importance to patients who have injuries about joints.

We must realize the date at which the epiphyses appear. We must realize the progress of ossification, and that at times irregular ossification proceeds within the epiphyses—that the epiphysis does not unite with the diaphysis entirely at the same period. More important is the fact that the epiphysis bears a definite relationship to certain lines along the diaphysis.

The appearance of the epiphyses for the acromion process between the ages of 14 and 16 years offers abundant opportunity for considering a normally developing epiphysis as a fracture. The epiphysis for the olecranon process appears between the ages of 11 and 14 and all too often gives ample opportunity for errors in diagnosis. Patients are at times treated for fractures of the olecranon when there is nothing wrong with the joint.

When there has been an injury about the elbow, particularly if it affects the inner aspect, fracture through the epiphysis for the internal epicondyle offers an easy possibility of error.

One should not overlook the fact when looking at the *x*-ray picture of a child's hand, that the epiphysis for the first metacarpal is at the upper end just as the phalanges are, whereas the epiphyses of the other metacarpals are at the distal end. This particular fact has given rise to speculation and experimental investigation, particularly in the studies of comparative anatomy, as to whether the first metacarpal is not in reality a phalanx, whether in the evolutionary process the first metacarpal has not actually become a vestigial remnant or entirely disappeared.

In the lower extremities the epiphysis for the lesser trochanter, which does not appear until about the ninth or tenth year, sometimes appears like a scale-like fracture.

One of the most conspicuous illustrations of opportunity for error is the appearance of the tubercle of the tibia. This is not infrequently mistaken for Osgood-Schlatter's disease, and so treated. I remember a doctor who interpreted the normal downward outgrowth of the tubercle of the tibia

as a fracture and suggested to the family that it needed to be either screwed or nailed down. Fortunately the family called in a consultant who realized that the patient did not have an injury to the tubercle of the tibia but in reality had a dislocated semilunar cartilage. This was operated on and the patient had a good knee thereafter.

In the foot the epiphysis for the posterior of the os calcis also offers opportunity for errors in interpretation on the part of those who are not conscious of the normal appearance. Too much emphasis cannot be laid on the importance of studying the normal appearance before attempting to interpret the *x*-ray. *X*-ray pictures are of great value in children, but this is entirely dependent upon the interpretation of the findings.

The great value and protection afforded by the elastic epiphyses to the growing individual against fractures in certain locations has long been a source of interest and speculation to many of us. I am sure that everyone interested in the subject of fractures has noted that fractures of the clavicle in the very young occur more often than fractures of the head of the humerus, the elbow or the base of the radius. At a little later period supracondylar fractures occur more frequently than fractures at the base of the radius, and as we approach adult life, fractures of the base of the radius with the same mechanism, occur more frequently than do supracondylar fractures.

The epiphyses apparently have greater elasticity and consequently act as cushions. When a child falls on his outstretched hand, the force is transmitted to the lower end of the humerus and a fracture just above the elbow results. At a later date when the epiphysis at the base of the radius has ossified, the same amount of hyperextension causes a fracture of the base of the radius, as the force is expended before it reaches the lower end of the humerus. This is purely speculative—an attempted explanation of the mechanism of fractures occurring in different locations when force is directed in the same direction in individuals of different ages.

SUMMARY

Disturbances of the epiphyses result from many causes other than trauma.

As much or more information can be obtained from the radiologic appearance of a joint as can be obtained from metabolism studies in certain endocrine disorders.

Skeletal disturbances characterize retardation phenomena such as are found in dyschrondroplasia.

Much can be gained by studying the normal joint appearance before one attempts to treat epiphyseal lesions.

BURSITIS

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INFLAMMATION may develop in any of the constant or adventitious bursae of the body. (Fig. 1.) A laceration or abrasion of the skin serves as a portal of entry for pyogenic organisms which may reach the bursa and cause an acute infection. Any of the bursae, even the deeper ones, may become infected from a contiguous abscess or very rarely a hematogenous bursitis may be caused by blood borne bacteria. This inflammation may become chronic. A bursa may be contused or torn by direct or indirect injury resulting in an acute traumatic bursitis which may also become chronic. In addition, frequent or repeated traumata result in chronic irritation and sometimes chronic inflammation without any acute phase. Tuberculous infection of a bursa is usually found only when the bursa connects with or is in very close proximity to an infected joint. Only rarely is it found as a separate entity. The same is true of syphilitic infection. Metabolic disturbances, such as gout, as well as the endocrinopathies, toxic disorders, foci of infection, etc., have been held responsible for some cases of chronic bursitis. Their causal relationship is certainly not proved, although they may be aggravating factors. The condition is found, for the most part, in adults; it is slightly more frequent in the male than the female.

The pathologic picture depends upon the etiology and the stage of the process. In the acute pyogenic infections, the reaction is the same as that found in the inflammation of other serous cavities, i.e., extravasation of fluid and white cells into the layers of the bursal wall, followed by the outpouring of fluid into the sac. The fluid at first is usually serous, but later may become seropurulent or even purulent. As the process subsides, the wall is thickened with scar tissue and often strands of fibrous tissue extend into the sac as pedunculated tags or even form a network and connect various parts of the bursa. In the acute traumatic bursitis, there is a tearing of the wall and an extravasation of serosaguineous fluid into the cavity. This later becomes replaced with fibrous tissue. In cases due to chronic trauma, there is a gradual thickening of the wall until sometimes the entire bursa becomes a greatly enlarged, fibrous mass with almost complete obliteration of the cavity.

The development of calcification in a chronicly inflamed bursa is an interesting and important complication. Calcification is frequently found in old tuberculous processes which are fibrotic and without adequate blood supply. Calcification and even ossification frequently develop in a hemorrhagic area in an injured muscle. Calcification develops in a bursa when sufficient fibrosis exists, when the hydrogen ion concentration is ideal and when the blood supply is inadequate. With a normal calcium in the blood stream, there is no reason to believe that decalcification of neighboring bone is necessary. It has been shown that the lime salts found here correspond chemically to bone, but it does not follow that they are derived directly from the bone. Just as the calcification occurs when all the physical conditions are ideal, so it may disappear when the processes are reversed.

Pain results as a natural accompaniment of the inflammation. If there is a severe, acute inflammation, the patient shows a marked systemic reaction. In all cases, the pain is increased on motion and motion of the part may be restricted, not only because of the pain but also because of fibrosis. The pain is increased when the

bursa is palpated by the examiner or compressed or stretched by muscular effort of the patient. Not only is tenderness found on palpation but in the superficial bursae with any fluid and in the deep bursae with considerable fluid, fluctuation is noted. The *x*-ray shows calcification if it is present and often, even though there is no calcification, the distended bursa may be seen.

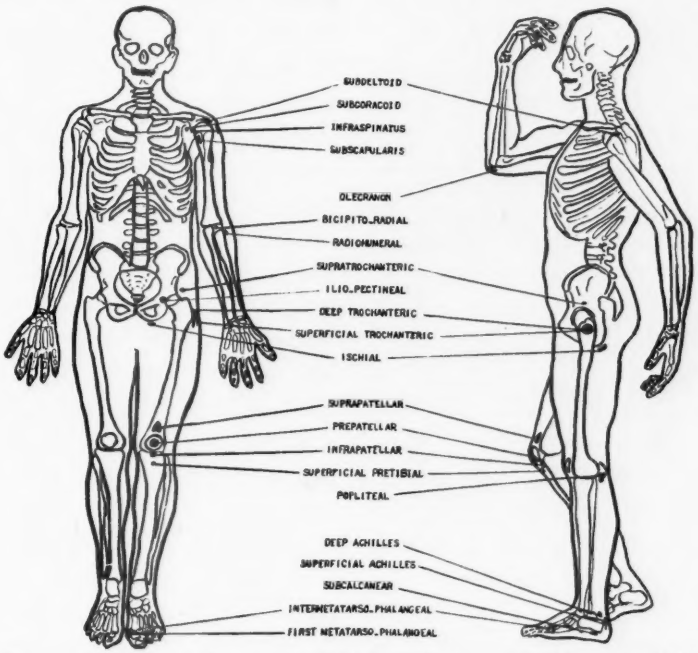

Fig. 1. Diagrammatic representation of the important bursae of the body.

The diagnosis of bursitis can usually be definitely made; the term should not be used to describe indefinite and undiagnosed periarticular disorders. If the bursa is superficial, the diagnosis offers no difficulty. If calcification is found in the region where a bursa is known to exist, the diagnosis is usually certain. It must be remembered, however, that it is possible to have a chronic bursitis even though there is no calcification and sometimes calcification, which seems to be in a bursa, is actually in an adjacent tendon or fascial area. In some of the deeper bursae, diagnosis is made only on exploratory operation. Muscular and ligamentous sprains, acute and chronic tuberculous and non-tuberculous arthritis or synovitis, osteomyelitis, osteitis, periostitis, etc., must be differentiated. Under proper treatment, the patient should expect complete relief.

The treatment in the mild acute case is rest and the use of heat or, very rarely, cold applications. If there is fluid in the bursa, aspiration, followed by a pressure bandage is necessary. Sometimes obliteration of the bursal sac can be accomplished by the injection of a sclerosing solution following aspiration. In more acute inflammation, especially when pus is present, the bursa should be widely incised. In the chronic cases, rest and heat, especially short wave radiation, will often relieve. In some special bursae, relief has been reported by rupture of the bursa and bursal pain has been relieved by *x*-ray radiation. The calcium in a bursa usually disappears in time with or without treatment, although the use of short wave is thought to hasten its absorption. Sometimes, when there is severe pain because of acute distention of the bursa due to a calcified mass, incision and curettage, injection of novocaine, or irrigation with saline may be used. In some cases, where the pain persists in spite of more conservative treatment, it may be necessary to excise the bursa. Bursae, especially the

subcutaneous ones, should not be excised indiscriminately, however, as they often act as essential pads or lubricating sacs.

SPECIAL TYPES OF BURSITIS

Subdeltoid or Subacromial. This is the largest bursa about the shoulder. Not only is it involved more frequently than any other bursa here, but also its involvement is the most common cause of shoulder disability. According to Haggart and Allen,[1] 79½ per cent of 300 cases of painful shoulder were due to "pathology in or related to the subacromial bursa and tendons of the short rotator muscles." This bursa is a multilocular sac and often made up of connecting, but sometimes distinct, subacromial and subdeltoid portions. It very seldom communicates with the shoulder joint. Involvement of this bursa may be either acute or chronic.

The *acute traumatic type* may be due to direct or indirect trauma; that is, it may be a contusion or laceration, or it may be associated with injury of the supraspinatus tendon, acromion or shoulder joint. There is usually no history of previous disease. There is severe pain in the shoulder which is increased on abduction and external rotation, especially when these motions are resisted; abduction and external rotation are also markedly limited. If there is a rupture of the supraspinatus tendon or other serious injury, this must be repaired. If it is thought that the bursa alone is damaged, immobilization and use of heat for a week or ten days followed by careful massage and manipulation are used.

The *acute bursitis with calcification* presents a somewhat similar picture, except that the symptoms are usually more severe. The usual history is that the patient underwent a prolonged or unusual exertion, or that he jerked his arm and felt or heard a snap in his shoulder. The shoulder remained somewhat painful, but not unbearably so. During the night that followed, or possibly within the next day or two, he was seized with a sudden and unbearable pain in his shoulder. Sleep was impossible and when the patient presents himself to the physician he is suffering exquisite pain and is most fearful that the examiner will touch or move his shoulder. The joint may appear somewhat swollen. The patient may be willing to demonstrate a little active flexion and extension, but absolutely no abduction. Passive motion is somewhat more extensive than active, but there is usually little or no abduction; if this motion is present, pain will be felt when the bursa slides beneath the acromion. Palpation demonstrates marked and well-localized tenderness over a point immediately lateral to the tip of the acromion. The *x*-ray shows the area of calcification in the floor of the bursa or in the tendon of the supraspinatus.

Many methods are used in the treatment of this condition. In our experience, rest and short wave therapy relieve a large percentage. Usually, the patient need not be hospitalized, but the arm should be placed in a sling with a pad in the axilla. A single short wave treatment of forty-five to fifty minutes is given at once, or, if the patient is in the hospital, two thirty to forty minute treatments are used. The next day the patient usually reports the best night since the onset of his trouble. If the patient does not get relief after a few treatments, irrigation with saline as advised by Patterson and Darrach[2] may be done. Some advise cold packs instead of heat for the first few days. Codman[3] suggests incision under novocaine and expulsion of the calcareous material. Ferguson[4] advises injection of novocaine and Lattman and Merritt[5] use *x*-ray radiation. The physician will use the treatment with which he has had the most experience and with which he gets the best results.

The patient is allowed to keep the arm in a sling for a few days. Usually within less than one week the pain will have lessened and the patient is encouraged to spend as much time as he can during the day with the arm slightly abducted, perhaps resting on a pillow or arm of a chair. Careful examination will demonstrate whether muscular

rigidity is developing. If it is not, no passive movements are carried out during the first week, lest the bursitis be aggravated. If the muscles seem to be getting spastic, abduction must be secured by means of a splint in order to prevent the shoulder from becoming fixed in adduction. As soon as the pain subsides, careful massage and mobilization are carried out, the area directly over the bursa being avoided in the massage. The more radical procedures are not necessary in the usual case. As a rule, the calcification disappears and so there need be no concern about leaving it as a permanent cause of irritation. Those who advocate immediate irrigation with saline state that they are saving the patient several days of disability, but the average patient would rather have a few more days of disability than be subjected to irrigation, especially by inexpert hands.

Chronic adhesive bursitis or *periarthritis* of the shoulder is a frequent sequela of improperly treated acute cases, or may occur as a gradual and insidious process. If the shoulder has not been properly mobilized, adhesions develop both within the bursa and in the muscular and periarticular structures. The patient complains of a more or less constant pain in the shoulder, but he is bothered especially by the lameness or inability to use the arm normally, as in combing the hair, dressing, etc. Examination discloses marked limitation of motion. In these cases, it is desirable to give intensive heat, massage, passive motion and manipulation. Often the range of motion can be increased by these means so that the patient is satisfied. If it cannot be, careful manipulation under anesthesia is desirable. This should be followed by a few days of immobilization in the abducted position and then intensive heat, massage and active and passive movements.

In the *chronic bursitis with calcification*, the symptoms are much the same, except that there may be less restriction of motion, but more pain when the arm reaches the horizontal position. There is localized tenderness and the *x*-ray shows the calcification. (Fig. 2.) Prolonged short wave treatments with massage and active and passive motion are usually effective. Operative removal of the calcified deposit is not advisable in the usual case as the deposit is not necessarily the cause of the pain and is removed with the greatest difficulty when it is in the supraspinatus tendon. Sometimes the pain and disability are worse following operation. If necessary, anesthesia and manipulation, as described above, may be used.

Fig. 2. Calcification in the subdeltoid bursa of a woman of 36 years. Pain and disability have been present for two years. Abduction is limited to 135 degrees. Two irrigations, the last under fluoroscopic control, failed to remove the calcification. The mass was penetrated by the needles with considerable difficulty and some fibrous tissue and calcified material were washed out. A prolonged course of inductotherm treatments with massage and manipulation is regarded as the best treatment and is being used.

Subscapularis. This bursa, which lies between the tendon of the subscapularis muscle and the anterior aspect of the capsule of the shoulder joint, may become inflamed. Active and passive motion of the shoulder are limited and painful, resisted adduction and internal rotation especially causing pain. Crepitus may be felt. Tenderness over the subcoracoid region is found and sometimes calcification is visible in the *x*-ray. If calcification or thickening of the bursa is present, it may be desirable to

excise it; rest and heat should be given a good trial first, however.

Infraspinatus. The small bursa under the tendon of the infraspinatus is sometimes the seat of an inflammation. Usually, however, it is found involved secondarily to disease of the shoulder as it often communicates with this joint.

Coracoclavicular or Subcoracoid. Involvement of this bursa closely resembles disease of the shoulder joint and sometimes exploration is necessary to confirm the diagnosis. If chronic inflammatory thickening of the bursa or calcification is found, excision is desirable.

Olecranon (Miner's Elbow). This is a superficial subcutaneous bursa which may become infected and acutely inflamed by open laceration or extension from a cellulitis. An acute traumatic bursitis can be set up by a contusion over the olecranon, which is especially likely to occur in a bursa already chronicly inflamed. Repeated minor traumata of the bursa may cause an irritation here and a chronic inflammatory process.

The *acutely inflamed bursa* shows the typical inflammatory reaction of the wall and an outpouring of serous, seropurulent or even purulent material into the sac. The patient notices a fluctuant swelling and pain, the intensity of which depends upon the degree of inflammation. Reddening of the skin and an increase in surface temperature are found if infection is present. In the differential diagnosis, cellulitis without involvement of the bursa, osteomyelitis, etc., must be differentiated. Wide incision of the skin, subcutaneous tissues and bursa is necessary.

The *chronic* case shows the typical inflammatory reaction with a variable thickening of the wall and the fibrous network within the sac. There may be little or no pain even though acute trauma has caused an extravasation of fluid. Some tenderness, but no increase in surface temperature is found; if fluid is present, there is fluctuation. Calcification is very seldom present. Sprain-fracture of the olecranon, osteomyelitis, osteitis, periostitis, etc., must be differentiated. Fluid should be aspirated, if it is present, and a pressure bandage applied. It may be necessary to repeat the aspiration, or, if desired, aspiration may be followed by the injection of 2 or 3 c.c. of a 5 per cent solution of sodium morrhuate or the same amount of a 5 per cent solution of quinine and urea hydrochloride. Before injecting a sclerosing solution, one must be certain that the bursa does not communicate with the elbow joint, but this condition is found very rarely. Excision of the chronicly inflamed bursa which does not respond to other treatment can be easily performed, but it should not be done without due consideration, as this bursa acts as a very efficient protector of the olecranon.

Bicipitoradial. Pain and tenderness about the tendon of the biceps brachii just short of its insertion may be due to inflammation of the bursa beneath the tendon. Sprain of the tendon or a tenosynovitis give similar symptoms, but usually the tenderness of bursitis is quite localized and seems to be behind the tendon. Tenderness in sprain of the tendon is found somewhat more distally and usually is more diffuse, while tenosynovitis shows crepitus, more widespread tenderness and perhaps swelling. In all these conditions, pain is increased when the elbow is flexed against resistance. The bursitis may be precipitated by prolonged or unusual use of the biceps, as the resumption of bowling in the fall. Time, rest and heat will usually relieve; rarely is it necessary to excise the bursa.

Radiohumeral. There is a condition frequently seen in which pain is present over the lateral epicondyle of the humerus with radiation down the dorsum of the forearm and an associated weakness of the grip when the forearm is pronated and the wrist flexed. This condition is usually referred to as "tennis elbow." In 1922 Osgood[6] reported his personal case of this condition in which it had been found that the disorder was due to an inflammation of a bursa beneath the conjoined tendon of

the extensors of the wrist. He concluded that most cases of "tennis elbow" are due to this bursitis; this explanation is generally accepted in this country, but less generally abroad.

In 1936 Cyriax[7] reported a series of cases in which he reviewed the possible causes of this condition. He concluded that a great majority of the cases were due to a periostitis, secondary to tears of the tendinous origin of the extensor carpi ulnaris. He stated that, in his experience, bursitis did not account for more than 1 or 2 per cent of the cases. He also mentioned that synovitis or arthritis of the radiohumeral joint, adhesions, gout, neuritis and tears of the capsule, ligaments or muscles, etc., had been variously blamed for the condition.

Repeated pronation and supination of the forearm or continuous or unusual exertion with the forearm pronated often cause this disorder. This latter position is used by tennis players in their backhand stroke, by carpenters in their use of the saw or hammer, and by plasterers when working on a ceiling, by fishermen in fly casting, etc. The diagnosis of "tennis elbow" is easily made by finding tenderness over the upper forearm immediately distal to the lateral epicondyle and an increase in the pain here when the patient completely flexes his fingers with the forearm pronated and the wrist already flexed. To determine whether or not the disability is due to a bursitis is very difficult. Usually, exploratory operation fails to reveal the presence of a bursitis.

In general, the treatment will be the same, no matter what the cause of the disability. Time and rest will bring relief in the course of several months. Hannson and Horwick[8] advise that the forearm be immobilized on a cock-up splint and that heat and massage be applied. Cross-hatching with many layers of adhesive will sometimes relieve. Carp[9] states that he cured four out of eight patients by rupture of the bursa under digital pressure. Alcohol and novocaine injections, operative resection of the muscles as they arise from the epicondyle or removal of the synovial fringes of the radiohumeral joint have also been recommended. Cyriax, who champions the theory that a great majority of these cases are due to incomplete periosteal tears, states that "tennis elbow" responds to manipulation without anesthesia. Cases which do not respond to these conservative measures should be operated upon, the tendon sectioned and the bursa removed.

Iliopsoas or Iliopectineal. Involvement of this bursa is much more prevalent than is commonly thought, since Connor[10] in 1933 presented thirty-three cases of his own, stating that only thirty-seven cases had been reported previously. The bursa is a constant one and is located between the tendon of the iliopsoas and the iliofemoral ligament. It connects with the hip joint in 15 per cent of the cases. The bursa is injured when a strain is placed upon the iliopsoas muscle, as in violent hyperextension of the hip, or when the iliopsoas is suddenly contracted. Pain, which may be referred to the knee, is found if the bursa is involved. Examination reveals weakness of the extremity, tenderness immediately over the bursa, and swelling if there is sufficient fluid present. (Finger[11] reported a case which yielded 210 c.c. of fluid on aspiration.) Pain on motion, especially adduction, extension and internal rotation, is usually present. The hip may be held in abduction, flexion and external rotation.

Inguinal or femoral hernia, abscess from tuberculosis of the spine or hip, swollen lymph glands, dilatation of the femoral vein or artery, or neoplasm also may cause swelling here. Many other conditions, such as kidney stone, arthritis of the hip, etc., may cause pain in this region without swelling. In tuberculous disease of the hip joint, the bursa is involved when it communicates with the joint. Rest and heat relieve the usual case; if not, traction or a plaster cast should be used. Aspiration is desirable if there is embarrassing fluid present; excision of the bursa may be necessary. It is important to realize the possibility of

disease of this bursa. O'Connor reports a case which was at first thought to be hip disease. Incision was made through both bursae and hip, so that the hip joint, which was free of disease, was contaminated and caused to ankylose.

FIG. 3. Calcification in the supratrochanteric bursa of a man of 33 years. He demonstrated tenderness in the gluteal and supratrochanteric regions following a fall. *X*-rays taken immediately revealed the calcified masses. After thirty inductotherm treatments over a three month period, *x*-rays were repeated and showed that the calcification had entirely disappeared.

Deep Trochanteric. This bursa is constantly found between the greater trochanter and the tendon of the gluteus maximus. Its inflammation is usually subacute or chronic and not associated with the accumulation of fluid. Pain and tenderness are found over the greater trochanter, the pain being increased on resisted external rotation. Pyogenic infection of the bursa with considerable purulent exudate may be found. In this case, the fluid will extend under the gluteus maximus, obliterating the depression immediately back of the trochanter and some gluteal pain and even sciatic radiation may result. Calcification of the bursa may be demonstrated in some cases by *x*-ray.

Arthritis of the hip, sacroiliac joint or even lower lumbar spine, osteomyelitis of the femur, etc., may cause pain in the region of the trochanter and must be differentiated. We have seen several cases of Marie-Strümpell arthritis whose first symptom was pain over one or both trochanters. The important diagnostic point is pain on resisted internal but not external rotation. There is also tenderness directly over the trochanter. Rest and heat usually relieve the chronic forms, although excision may be necessary, especially when there is extensive calcification. Wide incision should be made in the acute pyogenic infections.

Superficial Trochanteric. An adventitious bursa may develop between the skin and the greater trochanter in those whose hips are subject to chronic occupational trauma. It is involved less frequently than the deep bursa. Usually the symptoms are less severe and the tenderness more superficial. The same treatment is used as is used in the deep trochanteric bursitis.

Supratrochanteric. There are several inconstant bursae about the tendinous insertion of the gluteus medius which may become inflamed. Goldenberg and Leventhal[12] reported 5 4/10 per cent of 515 routine hip *x*-rays of patients between 15 and 69 years showed supratrochanteric calcification. The patient complains of pain in the hip, which may be increased on abduction, but usually the diagnosis depends upon the finding of calcification by *x*-ray. (Fig. 3.) Rest and short wave heating and massage usually completely relieve, and operative removal is seldom indicated.

Ischial or Ischiogluteal (Weaver's Bottom). This is a superficial and subcutaneous bursa which may develop over the ischial tuberosity in those whose occupation causes them to spend considerable time sitting on a hard surface. In cases where there is a bursitis, a tender, fluctuant swelling is found. The diagnosis offers no difficulty. Aspiration, or rarely excision, may be necessary.

Popliteal. Cystic swelling in the popliteal region is frequently found and there

are several constant and other inconstant bursae here which may be responsible for these swellings. In 1877 Morant Baker[13] reported eight cases of popliteal swelling which he regarded as cysts, the majority of which communicated with the knee joint. Haggart,[14] in April, 1938, reported operations during the preceding four years upon twelve patients with popliteal swelling and stated that nine of these were herniations of the knee joint, one was a bursitis of the semimembranosus bursa, one was a lipoma, and the last a diffuse hypertrophy of the subcutaneous fat pad. In October of 1938, Wilson, Eyre-Brook and Francis[15] reported that between 1928 and 1938, twenty-one cases of popliteal cyst were operated upon at the Hospital for the Ruptured and Crippled. In fifteen cases, a cyst was found which communicated with the knee joint, and it was their opinion that these cysts were actually distensions of the gastrocnemius bursa. It is a question, then, whether these popliteal swellings are herniations of the joint or bursae, as their structure is identical and their communication with the knee joint very inconstant and incomplete.

There are several bursae in this region. A constant one (anserina) is found over the tibial collateral ligament and beneath the tendons of the gracilis, semitendinosis and sartorius. Another is found beneath the tendon of the semimembranosus and the collateral ligament of the tibia and another between the medial head of the gastrocnemius and the capsule over the inner condyle of the femur. Sometimes one is found between the semimembranosus and medial head of the gastrocnemius. These latter two often communicate.

Involvement of a popliteal bursa may occur at any age and trauma is the usual cause of the disorder. Pain is an early symptom and may precede the finding of visible swelling. In many cases, painless swelling is the only complaint, the swelling being most prominent when the knee is extended. Usually, even though the sac does not connect with the knee joint, there is pain in and restriction of motion of the joint and signs suggesting internal derangement. It may be impossible to say whether the swelling is a cyst or a bursa, but it should be determined whether or not it communicates with the knee joint. In some cases, there is a very definite communication and the interchange of fluid can easily be demonstrated by exerting pressure over either the patella or the swelling. In other cases, an *x*-ray after air injection is necessary to differentiate.

Small bursae with mild symptoms may be ignored and may disappear spontaneously. In some instances, aspiration may be desirable. In cases where swelling persists and is sufficient to interfere with joint function, complete excision is necessary.

Prepatellar (Housemaid's Knee). This is one of the large, subcutaneous bursae which often becomes inflamed in those who kneel a great deal, or who receive frequent contusions on the anterior aspect of the knee. Also, it may become acutely inflamed because of infection by a pyogenic organism through an abrasion or laceration of the skin. This will cause an acute inflammatory reaction of the bursal wall with the development of a seropurulent or purulent exudate in the bursa. In most cases, there is a gradual thickening of the wall due to constant trauma, and then, after an unusually severe trauma or other cause, there is a marked outpouring of serous fluid. This may amount to as much as 100 c.c. In other cases, the thickening of the bursal wall may continue and concentric rings of fibrous tissue be laid down, so that it is several centimeters thick and the lumen is all but obliterated. The diagnosis of this condition offers no difficulty because of the superficial nature of the bursa. The treatment in the acute purulent case is wide incision and drainage. Usually two lateral incisions are made in order to avoid a scar on the anterior surface. In the acute exacerbations with accumulation of fluid, it is necessary to aspirate and apply a pressure bandage.

This may be repeated several times if necessary. A sclerosing solution may be injected following aspiration in cases which

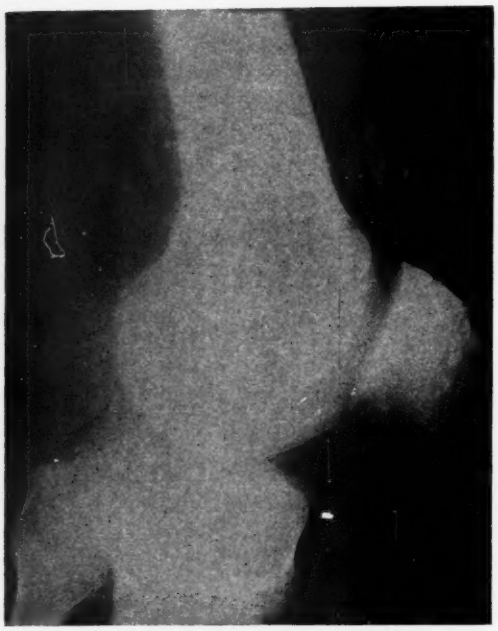

Fig. 4. Calcification in the suprapatellar bursa of a 38 year old man with chronic, long-standing pulmonary tuberculosis. The suprapatellar region was swollen and tender, but these symptoms lasted but a few months. The bursa was not explored.

tend to refill. Carp[16] uses 2 to 3 c.c. of 3½ per cent iodine. Five per cent sodium morrhuate, 5 per cent quinine and urea hydrochloride, or 3 per cent carbolic acid may be used if preferred. Excision of the bursa is seldom justified as it removes a very necessary protective cushion from the anterior surface of the patella and only in very chronic cases where there is marked inflammation and thickening of the wall should this be done.

Suprapatellar or Quadriceps. This bursa lies between the quadriceps tendon and the lower end of the femur. According to Spalteholtz, it communicates with the knee joint in 85 per cent of the cases. It is possible to determine whether this communication exists by exerting pressure over either the patella or the bursa and noting whether there is an increase in fluid in the other region. It is obvious that, when there is a communication with the knee joint, involvement of one means involvement of the other and the treatment will be directed toward relieving the primary disorder.

Sometimes, inflammation may develop in a bursa which does not communicate with the knee joint. In this case, a painful, fluctuant swelling develops above the knee and is especially evident under and on either side of the quadriceps tendon. Calcification may be demonstrated by *x*-ray. (Fig. 4.) In the usual case, aspiration followed by rest and heat will relieve. Repeated aspiration may be necessary. A case of tuberculous infection of the bursa without involvement of the knee was reported by Stewart.[17]

Deep Pretibial or Infrapatellar. This is a constant bursa found between the patellar ligament and the anterior surface of the tibia, not communicating with the knee joint. It is frequently involved. Pain immediately below the knee is found and inspection may show that the usual depressions on either side of the ligament are filled out. In addition, there will be an increase in the pain here on resisted extension and tenderness on palpation. Synovitis, arthritis, disorders of the patellar fat pad and other internal derangements of the knee must be differentiated. Rest and heat will usually relieve. A posterior splint may be used to immobilize the knee, yet allow the patient to remain ambulatory. Aspiration may be indicated and possibly the injection of a sclerosing solution. Excision is seldom justified.

Superficial Pretibial. This bursa is sometimes found under the skin, superficial to the tibial tendon at its attachment to the tuberosity. The diagnosis is made by finding a tender, fluctuant swelling here. Rest and heat usually relieve; if not, aspiration or, rarely, excision is necessary.

Retrocalcanear or Deep Achilles (Albert's Disease). Painful heel or achillodynia may be caused by inflammation of the bursa which lies between the tendo Achillis and the calcaneus. Trauma is the usual cause of the involvement and pain and

swelling may be the patient's complaints. The pain is increased when the tendon is made to contract against resistance and tenderness is elicited at either side of the tendon, immediately short of its insertion.

There are many other causes of achillodynia, which must be differentiated. Tenosynovitis usually shows swelling, diffuse tenderness and perhaps a silky crepitus along the course of the tendon. Sprain of the tendon shows more localized tenderness over the point of insertion. Apophysitis of the os calcis, which is found only in the first two decades of life, and periositis are both demonstrable by *x*-ray and usually cause more widespread tenderness.

In the average case, relief may be gotten by the application of a felt pad under the heel and an extensive adhesive plaster strapping which relieves the tension on the tendon. The stiff counter of the heel should be removed. A few days' complete rest is justified if ambulatory treatment does not relieve, and in rare cases excision may be necessary.

Superficial Calcanear or Posterior Achilles. A subcutaneous bursa may develop over the most prominent posterior aspect of the calcaneus. It is generally due to unusual pressure, as from a stiff counter on the shoe. The diagnosis is not difficult, as a superficial, tender, fluctuant swelling covered by a calloused area develops. The condition is easily relieved by removing the stiff counter of the shoe. The painful callous should be treated by the application of 10 per cent salicylic acid ointment. The bursa should not be excised, as it acts as a natural cushion for the calcaneus.

Subcalcanear. There is usually a bursa under the tuberosity of the calcaneus at the point of greatest weight bearing. There may be additional bursae over the anterior, as well as midcalcanear areas. Acute or chronic trauma is usually responsible for their irritation. Sharp local pain with radiation into the leg is found. Foot strain, calcanear spurs, etc., must be differentiated. Rest and hot applications relieve the acute cases. A steel support with a cupped heel or a ledge which removes the weight from the tender area should be used in the chronic cases. If this does not relieve, excision may be necessary. Hertzler[18] is of the opinion that surgical excision followed by packing of the wound with gauze saturated with a 3 per cent iodine solution is the best treatment for the chronic cases.

First Metatarsophalangeal. An adventitious bursa may develop over the mesial aspect of the first metatarsophalangeal joint in cases of hallux valgus. The diagnosis of "bunion" is readily made by the patient. Excision of the bursa without osteotomy for correction of the hallux valgus is seldom justified. Properly performed operation for correction of the bony deformity relieves the bursitis. In the acutely inflamed bursa, complete rest and relief of pressure are necessary and an ointment containing opium or other anodyne may be used. In some chronic cases where osteotomy is not indicated, temporary relief may be gotten by alteration of the shoe or by a splint or protector.

Intermetatarsophalangeal. There are four bursae between the metatarsal heads. If one or more of them becomes inflamed, a severe metatarsalgia results, although metatarsalgia is not usually caused by a bursitis. In rare cases, there may be sufficient fluid in the bursa to cause a tender, fluctuant swelling. If this is found, the bursa should be excised. Most cases of metatarsalgia, whether they are due to a burisitis or not, are relieved by a shoe of proper width, with an added metatarsal pad or bar. Exercises and hot soaks for the feet should also be used. In cases where conservative treatment does not relieve, and in those in which it is thought that there is a bursitis present, the painful area may be excised and curetted, thus obliterating the bursa.

REFERENCES

1. Haggart, G. E., and Allen, H. A. Painful shoulder—subdeltoid bursitis. *S. Clin. North America*, 15: 1537, 1935.

2. Patterson, R. L. Jr., and Darrach, W. Treatment of acute bursitis by needle irrigation. *J. Bone & Joint Surg.*, 19: 993, 1937.
3. Codman, E. A. On stiff and painful shoulder. *Boston M. J.*, 154: 613, 1906.
4. Ferguson, L. K. Painful shoulder arising from lesions of the subacromial bursa and supraspinatus tendon. *Ann. Surg.*, 105: 243, 1937.
5. Lattman, I., and Merritt, E. A. Treatment of subacromial bursitis by Roentgen irradiation. *Am. J. Roentgenol.*, 36: 55, 1936.
6. Osgood, R. B. Radiohumeral bursitis, epicondylitis, epicondylalgia (tennis elbow). *Arch. Surg.*, 4: 420, 1922.
7. Cyriax, J. H. Pathology and treatment of tennis elbow. *J. Bone & Joint Surg.*, 18: 921, 1936.
8. Hansson, K. G., and Horwich, I. D. Epicondylitis humeri. *J. A. M. A.*, 94: 1557, 1930.
9. Carp, L. Tennis elbow (epicondylitis) caused by radiohumeral bursitis. *Arch. Surg.*, 24: 905, 1932.
10. O'Connor, D. S. Early recognition of iliopectineal bursitis. *Surg., Gynec. & Obst.*, 57: 674, 1933.
11. Finder, J. G. Iliopectineal bursitis. *Arch. Surg.*, 36: 518, 1938.
12. Goldenberg, R. R., and Leventhial, G. S. Supratrochanteric calcification. *J. Bone & Joint Surg.*, 18: 205, 1936.
13. Baker, W. Morrant. On the formation of synovial cysts in the leg in connection with disease of the knee. *St. Bartholomew's Rep.*, 13: 245, 1877.
14. Haggart, G. E. Posterior hernia of the knee joint. *J. Bone & Joint Surg.*, 20: 363, 1938.
15. Wilson, P. D., Eyre-Brook, A. L., and Francis, J. D. Clinical and anatomical study of the semimembranosus bursa in relation to popliteal cyst. *J. Bone & Joint Surg.*, 20: 963, 1938.
16. Carp, L. Conservative treatment of prepatellar bursitis. *Surg., Gynec. & Obst.*, 52: 87, 1931.
17. Stewart, W. J. Tuberculous bursitis without adjacent joint involvement following trauma. *J. Bone & Joint Surg.*, 15: 626, 1933.
18. Hertzler, A. E. Bursitis of the plantar surface of the foot. *Am. J. Surg.*, 1: 117, 1926.

The calories in a lump of sugar will supply the brain with enough calories for a day of thought. This is true, however, only of the free and easy mind. Worry and nervous strain waste energy by increasing the muscular tension during the day and disturbing the sound sleep during the night.

The brief excerpts in this issue are taken from "Sensible Dieting" by William Engel (Knopf).

THE PLACE OF THE BIOPSY IN THE DIAGNOSIS AND TREATMENT OF TUMORS AND TUMOR-LIKE LESIONS OF THE EXTREMITIES

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EACH year one cannot help but be impressed by the steady progress of medicine in its attempts at solving many of the major problems with which it is confronted. At the same time more and more one is forced to the realization of the limitations of the individual in keeping up with this progress, even in his chosen field. As a result, the clinician has come to rely with ever greater frequency upon the pathologist for his opinion, both in respect to diagnosis and treatment, for the pathologist as a rule is in a peculiarly strategic position, depending as he does upon factual evidence obtained by examination of tissues or the various products of body metabolism.

Time was, and not so many years ago, when the pathologist was considered scarcely more than a glorified technician, relegated to the darkest corner of the hospital basement, where he was permitted to carry on his ghoulish investigations as best he might with the most inadequate facilities conceivable. Gradually he has emerged from his comparative obscurity to a position of relative importance in the organization of hospital medicine. And the time will come perhaps when he actually is recognized professionally as a physician and consultant along with the surgeon and internist, and may hope to share commensurately with them for services rendered. It *must* come, or else medicine will slip backwards, if good, honest, capable men cannot be attracted to the field of pathology for lack of an adequate living to be derived therefrom. In the last analysis, it is chiefly in the experimental laboratory that those studies can be made which carry medicine ever on and upward toward that ultimate goal, the control of all disease, whether it be pestilential, metabolic or neoplastic in nature.

It is with this point of view in mind, the desire to play a real part in contributing to the welfare of the patient, that the pathologist assumes his share of the responsibility in arriving at a diagnosis and in recommending any particular form of therapy. With the enormous strides which have been made in the past decade or so in the refinements of laboratory diagnosis, it is obvious that the busy surgeon or physician cannot be his own pathologist as was more or less true in the "horse and buggy" days only a comparatively few years ago. It is no longer sufficient merely to say, "this is a malignant tumor; it should be removed surgically." Too many ill-advised and unnecessary operations have been performed; too many lives sacrificed by the surgeon, from lack of adequate study of the case and too hasty decision, without the benefit of modern laboratory facilities and without consultation with his confrère, the pathologist. Only rarely does one encounter such men as Bloodgood, Hertzler, Graham, or Babcock, skillful surgeons and experienced tissue pathologists combined.

Nowhere does this need of coöperation show itself more fully than in the situation which exists in respect to the surgeon, the pathologist and the radiologist. They are mutually dependent upon each other in determining the proper course to follow in any given case. The old axiom, "two heads are better than one," can scarcely better be exemplified than in this relationship in

the care of patients suffering from neoplastic or suspected neoplastic disease. Gradation of malignant processes, confirmation of the clinical diagnosis, integration of the roentgenologic, clinical and pathologic findings are all vitally important to the patient and surgeon alike in deciding how any given case should be handled. If metastasis of an osteogenic sarcoma to the lungs has already occurred there would seem to be very little point in subjecting a patient to the trauma and shock of radical surgery by amputation. Giant cell tumors and Ewing's tumors are other examples where misguided enthusiasm is possible if surgery is generally employed as the method of choice in treatment. On the other hand, the *early* amputation of an extremity with an osteogenic sarcoma offers a nearly 20 per cent chance of cure, and is the *only* possible effective method of therapy. But immediate frozen section biopsy diagnosis by the pathologist at the time of operation in doubtful cases may save a leg which is the site of an atypical and confusing osteitis, osteomyelitis or even a xanthomatosis of the Hand-Christian-Schüller type.

	Benign	Malignant
I. Tumors of epithelial cell origin		
(*a*) Pavement cell type	1. Papilloma	1. Basal cell "carcinoma" (usually benign clinically) 2. Squamous cell carcinoma
(*b*) Glandular type	1. Sweat gland adenoma 2. Sebaceous gland adenoma	1. Adenocarcinoma 2. Adenocarcinoma
II. Tumors of connective tissue origin	1. Fibroma	1. Fibrosarcoma (including periosteal fibrosarcoma)
	2. Lipoma	2. Liposarcoma
	3. Myxoma (rare)	3. Myxosarcoma
	4. Chondroma	4. Chondrosarcoma } osteogenic
	5. Osteoma	5. Osteosarcoma } sarcoma
	6. Benign "giant cell" tumor of bone	
III. Tumors of hematopoietic and reticulo-endothelial system origin	1. Lymphoma	1. Lymphosarcoma 2. Lymphoid leukemia 3. Hodgkin's disease 4. Boeck's sarcoid 5. Myeloid leucemia 6. Plasma cell myeloma (multiple myeloma) 7. Endothelial myeloma (Ewing's tumor) 8. Erythroblastosis
IV. Tumors of muscle cell origin	1. Leiomyoma (smooth muscle)	1. Leiomyosarcoma 2. Rhabdomyosarcoma (striated muscle)
V. Tumors of pigment cell origin	1. Nevus (melanoma)	1. Malignant melanoma
VI. Tumors of nervous system origin	1. Neurofibroma (von Recklinghausen's disease)	
	2. Neurinoma	1. Neurogenic sarcoma
VII. Tumors of endothelial cell origin	1. Hemangioma (*a*) Capillary (*b*) Cavernous	1. Angiosarcoma (Kaposi's disease)
	2. Lymphangioma	2. Synovioma
	3. Glomus tumor	

Conservatism in surgery is again something to be deplored, when surgery is indicated. No surgeon wants to do a high amputation for a gangrene of the great toe. Yet from bitter experience he has learned that if the lesion is that of thromboangiitis obliterans, it will only be a question of time until he is confronted with the necessity of such a procedure, if he has contented himself by conservatively amputating the foot alone. Similarly in osteogenic sarcoma, there is no way of telling even by roentgenogram just how far along the medullary canal the tumor has extended, and the more radical the surgery, the higher creep the figures of recovery. But surely the surgeon is entitled to the moral support and sharing of responsibility by the pathologist before urging such a radical operative measure.

With these introductory comments regarding the place of the pathologist in the modern practice of medicine, let us turn to a consideration of the various tumors and tumor-like lesions of the extremities from the standpoint of pathologic diagnosis, particularly in its relationship to treatment. At first thought, one might dismiss the subject briefly with a discussion of the various bone tumors. As one reviews the field more carefully, however, one is confronted with what amounts to an encyclopedic presentation of oncology, for actually, with the exception of brain tumors, almost every other recognized type of tumor, either as a primary or a metastatic lesion, may be encountered in the extremities. The brief list on p. 294 gives in outline form the various primary neoplasms which do occur with varying degrees of frequency.

For convenience, the various tumors of bone are reassembled from the above classification and presented as a separate entity, making up as they do the largest and most important group of neoplasms of the extremities:

I. Benign tumors of bone
    1. Osteoma
    2. Chondroma
    3. Benign giant cell tumor (usually clinically benign, but subject to subsequent malignant transformation)
II. Malignant tumors of bone
    1. Osteogenic sarcoma
        (*a*) Sclerosing type
        (*b*) Osteolytic type
        (*c*) Telangiectatic type
        (*d*) Chondromyxomatous type
    2. Ewing's (endothelial myeloma) tumor
    3. Multiple (plasma cell) myelomata
    4. Periosteal fibrosarcoma
    5. Metastatic tumors (predominantly from breast, prostate, kidney [hypernephroma] and thyroid, less frequently from other viscera).

The great majority of this rather imposing group of neoplasms may be diagnosed readily clinically or by *x*-ray without the necessity of resorting to biopsy, but there still remains a very considerable group in which differential diagnosis may depend in the last analysis wholly upon microscopic study of the tissues, or in which the therapy may be materially influenced by a histologic evaluation of the neoplastic process. Furthermore there are many *tumor-like* lesions which add to the difficulties of the clinician, the roentgenologist and pathologist alike. It is in the recognition of this latter group of cases, and their differentiation from true neoplasms that biopsy studies are especially worthwhile. Among the more important, and more frequently encountered of these should be cited the following:

I. Lesions involving epithelium
    1. Verrucae (especially the large, flat verruca plantaris)
    2. Certain of the chronic granulomata—among them blastomycosis, streptothricosis and even the tuberculides
    3. Molluscum contagiosum
II. Lesions involving the soft tissues
    1. Ganglia of the tendon sheaths
    2. DeQuervain's disease (chronic tenosynovitis)

3. Gout
4. Myositis ossificans (especially the localized traumatic type)

III. Diseases of bone
1. Infectious lesions
   (*a*) Atypical osteomyelitis
   (*b*) Brodie's abscess
   (*c*) Sclerosing osteitis
   (*d*) Syphilitic osteitis and periostitis
   (*e*) Tuberculosis of bone
2. Metabolic and deficiency diseases
   (*a*) Osteitis fibrosa
   (*b*) Osteitis fibrosa cystica
   (*c*) Osteitis deformans
   (*d*) Scorbutus (rare)
   (*e*) Xanthomatosis (Hand-Christian-Schüller disease)
3. Miscellaneous conditions
   (*a*) Exostoses
   (*b*) Enchondroses

In a brief presentation of the subject such as this it is obviously impossible to go into any detailed discussion of the pathologic differential diagnosis of the entire gamut of conditions outlined above. Accordingly, the majority of these lesions may be dismissed briefly, reserving the greater part of our consideration for a few of the more troublesome problems of diagnosis and prognosis.

I. Epithelial Tumors. The benign tumors of the skin, as papillomata, may at times cause difficulty in diagnosis clinically. Their differentiation from verrucae and other chronic inflammatory lesions, from molluscum contagiosum, and if pigmented, from melanomata, not infrequently requires microscopic study of a biopsy fragment or of the excised specimen itself. In most such superficial lesions, excision is usually the method of choice in treatment. Immediate frozen section examination of the tissue is not ordinarily indicated, and the pathologist has a better opportunity to study the material under ideal circumstances, and is able to give a well weighed expression of opinion as to prognosis and further treatment. Especially in differentiating the simple pigmented papilloma and nevus from the malignant melanoma does this affect the prognosis for the patient and at times his subsequent treatment. Even the possibility of squamous cell carcinoma developing in such a papillomatous lesion must be reckoned with, and here again, the pathologic diagnosis may well be the determining factor in urging some life saving measure.

The adenomata of the skin developing from sebaceous or sweat glands and their malignant counterparts such as adenocarcinomata are an almost negligible group as far as the extremities are concerned. They exist more as pathologic curiosities than as diagnostic problems. The recognition of the lesion is certainly histologic in character, and probably as much a surprise to the pathologist as to the clinician.

Neoplasms of the basal cell type are relatively uncommon involving an extremity except in the very aged, in whom their significance is almost negligible. Rare instances of their occurence in a somewhat younger age group are recognized. In such cases the lesions are apt to be multiple, relatively cellular, and to present the cystic adenoid type of picture, more often associated with the small benign lesions around the eye. A woman 44 years of age provided one such case which provoked a considerable discussion and difference of opinion among pathologists to whom the biopsy material was submitted. There were over 200 small lesions scattered over both lower extremities which responded to irradiation therapy very satisfactorily. This type of tumor presents its usual histologic features characterized by a proliferation of the basal cells of the epithelium in a relatively orderly and noninvasive fashion. The value of the biopsy is seen in the occasional case in which the rate of growth of the lesion seems excessive, for now and again the squamous cell element becomes stimulated to neoplastic activity and the tumor presents a microscopic picture of actual malignancy requiring rather more radical therapeutic measures.

On the other hand, epidermoid (squamous cell) carcinomata of the extremity, while certainly not commonly encountered, can scarcely be considered as rare tumors. Most often seen on the extensor surfaces of the more exposed skin areas such as the back of the hand and wrist, they are found much more commonly in males. The age incidence, chiefly in the sixth and seventh decades, is likewise helpful in their recognition and differentiation from their more common basal cell counterpart. Usually of a relatively low grade malignancy, with well defined histologic differentiation of their cells, with "pearl" formation, keratinization, and the presence of intercellular bridges, their recognition at biopsy should be easy. However, when such adult cell characteristics are lacking, their separation from atypical inflammatory hyperplasias of the epithelium is a challenge to the pathologist at times, and his decision may be one of vital importance to the patient. Such tumors behave as squamous carcinomata elsewhere—by lymphatic metastasis—and extension to the regional lymph nodes in this instance may well mean axilla or groin—raising a difficult problem for the surgical approach, and modifying prognosis accordingly. Extreme care and long experience in interpreting the histologic findings under such circumstances are necessary if the patient is to obtain the best possible subsequent treatment,—and then only through coöperation of the surgeon and the radiologist.

II. Tumors of Connective Tissue Origin Other than Bone Tumors. Among the benign tumors of connective tissue origin which are encountered in the extremities, the fibroma is the only one occurring with any numerical frequency. Such tumors are usually small, discrete lesions immediately beneath the epithelium and apt to be fairly well circumscribed, although at times this demarcation is not too well maintained grossly. The tumors ordinarily are relatively small in size and their treatment is simple excision. Only in the instance of the larger lesions does any question of malignancy ordinarily enter, in which case, again, biopsy serves to establish the diagnosis. From the differential standpoint, further, if these tumors are multiple, as they not infrequently may be, and are associated with similar subcutaneous nodules elsewhere over the trunk, their possible confusion with the neurofibromata must be recognized. At times it is only with the use of differential staining methods that histologic examination can clear the issue.

Fig. 1. Left hand. Squamous cell (epidermoid) carcinoma of unusually advanced and malignant character.

More rarely, lipomata are encountered in the extremities, most often as part of a generalized lipomatosis. Their differential diagnosis from sebaceous cysts may at times occasion some difficulty clinically, but surgical removal and histologic examination serve to settle any such uncertainty.

Theoretically, myxomata might be encountered, but certainly only as extremely rare tumors. Personally, I have never in my experience observed such a tumor, either

as a benign or a malignant neoplasm, involving an extremity.

From the malignant standpoint, fibrosarcomata and liposarcomata may arise either upon the site of a preëxisting benign tumor of the same prototype, or as malignant lesions from the outset. Such tumors, particularly the fibrosarcomata, are by no means uncommon. This is especially true if one takes into consideration that group of sarcomata believed to arise from the periosteum as the so-called periosteal fibrosarcoma. Here, biopsy is of extreme prognostic value in differentiating the much less malignant periosteal sarcoma from other forms of bone tumor with which, not infrequently, they may be mistaken, both clinically and roentgenologically, invading as they frequently do the bone itself. Such tumors microscopically show all gradations of cellular differentiation from extreme anaplasia to relatively adult, compact growths with little evidence of activity, and with corresponding variation in their prognosis.

III. Tumors of Hematopoietic and Reticulo-Endothelial Origin. The tumors of the hematopoietic and lymphoid apparatus are relatively unimportant in respect to the extremities, in that they are usually merely manifestations of a rather widespread systemic process. If one were to include the occasional instances of primary lymphoma, lymphosarcoma, and Hodgkin's disease of the inguinal or axillary lymph nodes as lesions of the extremities, then their numerical importance would increase considerably as these sites are comparatively common in the development of such tumors. On the other hand, leucemic infiltration of the skin and bones is not materially affected either diagnostically or prognostically by biopsy examination. As in the case of the connective tissue tumors, the endothelial myeloma (Ewing's tumor of bone) deserves special consideration. It will be discussed in relation to the other bone tumors.

IV. Tumors of Muscle Cell Origin. Occasionally small myxomata arising from the erector pili muscles in the subcutaneous tissues are encountered which are usually diagnosed clinically as a variant of the fibroma. It is only by pathologic examination of the tissues microscopically after their removal that their differentiation from this other more common subcutaneous tumor is made. Like the fibroma, such tumors are not ordinarily of any serious prognostic significance. Among the really rare tumors of the extremities should be mentioned the rhabdomyosarcoma, a malignant tumor arising from striated muscle. In a fairly wide experience with surgical pathologic material, only one such case has been encountered, arising from the gastrocnemius muscle of a young male. This remained localized, except for infiltration of the bone. Recovery was complete following amputation.

V. Tumors of Pigment Cell Origin. In the pigmented group of neoplasms, on the other hand, we encounter one of the most important groups of tumors of the extremities. Nevi of varying degrees of pigmentation and epithelial overgrowth, ranging from huge, elevated, pigmented, hirsute lesions down to tiny areas scarcely more than a millimeter or two in size with little or no pigmentation, are found in large numbers. Size, the degree of pigmentation, the amount of epithelial papillation, and regularity of outline, individually are not safe criteria for clinical differentiation of malignancy. Many innocent-appearing, small tumors have been removed and submitted for pathologic diagnosis only to be reported as malignant melanoma, and to be followed by the death of the patient within a comparatively short period of time thereafter; while, on the other hand, some of the most malignant-appearing lesions clinically and grossly may, under the microscope, show not the slightest suggestion of actual danger.

Perhaps among the most important of these melanomata, from this standpoint, should be mentioned the non-pigmented (amelanotic) melanoma which is so frequently encountered arising as a subungual

nodule in relation to one of the toes. These are frequently mistaken for inflammatory lesions and treated at first conservatively, only to discover their malignant nature with the onset of widespread metastases. The importance of biopsy examination, preferably by immediate frozen section, in these cases cannot be over-emphasized, for radical surgery with amputation of the toe yields a very high percentage of permanent cures, if operation is performed sufficiently early.

More significant from the surgical standpoint are those localized tumors involving the peripheral nerves of the extremities, which in their benign state are spoken of as "neurinomata," and in their malignant form as "neurogenic sarcomata." These are tumors which often require extremely careful study under the microscope by an experienced pathologist to differentiate the benign from the malignant forms. The neurinoma, in itself, from the standpoint of life, is of little more significance than the benign tumors of connective tissue or smooth muscle origin, while the neurogenic sarcoma, on the other hand, is an extremely persistent tumor tending to become more malignant as time goes on and ultimately to metastasize and cause the death of the patient. Unfortunately, it is an extremely radioresistant tumor, Furthermore, one is confronted always by the possibility that the malignancy has extended far beyond

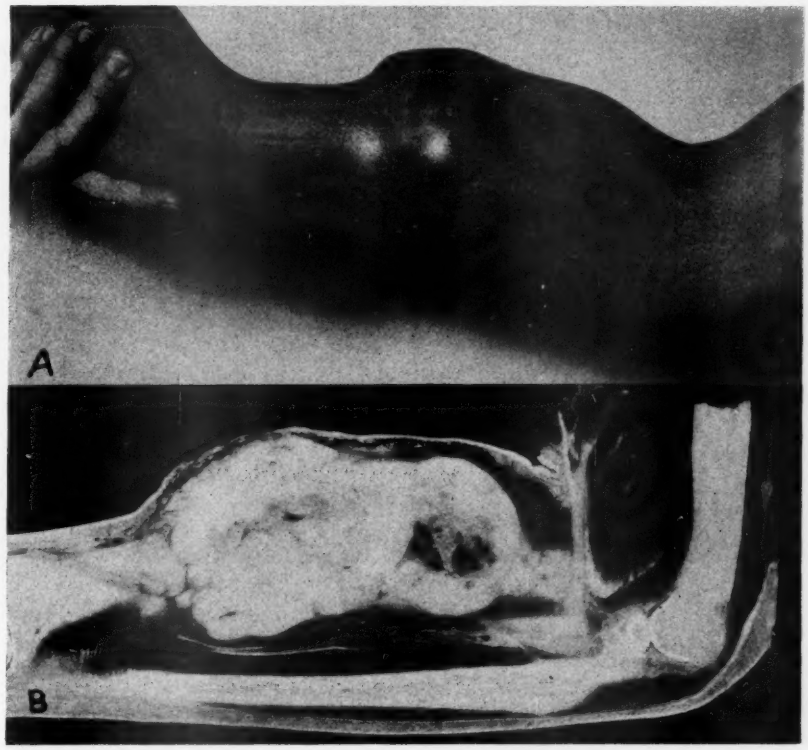

Fig. 2. Neurogenic sarcoma of arm. A, clinical photograph of patient's arm, showing location of tumor and its external appearance. B, sagittal section of amputated arm with its nerve trunk origin shown. Note absence of periosteal or bone involvement.

VI. Tumors of Nervous System Origin. The tumors of the nervous system which are found to involve the extremities are chiefly those relating to the nerve fibers. These range from the diffuse neurofibromatosis of von Recklinghausen's disease, in which not only lesions of the extremities are found, but widespread systemic involvement of the entire cutaneous nervous system.

the apparent local lesion and that the process is one which may recur at a point higher along the nerve trunk, even when diagnosis, in the first place because it is most frequently found as a subungual, minute, pinhead sized lesion; and secondly,

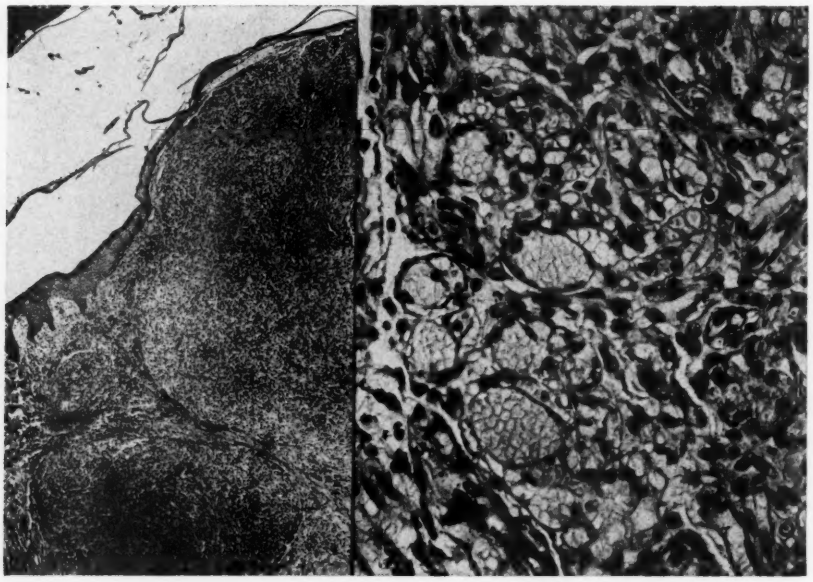

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FIG. 3. Kaposi's disease of foot. A, low power photomicrograph to illustrate typical subcutaneous location of lesions with thinned overlying epithelium. B, high power architectural detail—emphasizing essential angiomatous nature of lesion and its low grade malignancy histologically.

fairly radical surgery by amputation has been done.

VII. Tumors of Endothelial Cell Origin. Among the benign tumors which arise from angiomatous tissue must be mentioned the so-called "birth marks" or hemangiomata. Perhaps these should not be included as true tumors in any strict classification, as they are more probably developmental defects in the vascular system in intrauterine life and are congenital in nature. Similarly, the lymphangioma, best exemplified by the so-called hygroma colli, might better be included as a congenital defect and be discussed under the heading of teratology rather than oncology. But at times their recognition is only established by biopsy study of tissue removed surgically.

Of more interest in this group of benign tumors which affect the vascular system is the glomus tumor, a growth which involves the neuromuscular vascular anastomoses. Clinically, it should offer little difficulty in because of its involvement of the nerve fibers it is invariably one of the most painful lesions known. Its surgical removal results in permanent cure and the relief of the pain. Its diagnosis is merely confirmed by histologic examination.

On the malignant side, in the discussion of endothelial cell tumors, should be included that curious condition known as Kaposi's disease. This is believed by most pathologists to represent a true sarcoma of blood vessel origin and could well be spoken of anatomically as an angiosarcoma. For some curious and as yet unexplainable reason, the process almost invariably starts in one of the lower extremities and appears as nodular, purplish, cyanotic swellings of the skin which are frequently mistaken for some inflammatory process complicated by hemorrhage. The lesions are likely to occur in crops, which should lead the observant clinician to suspect the diagnosis. Biopsy examination reveals a rather characteristic picture of a

proliferative endothelial reaction of a sarcomatous nature as evidenced by numerous mitoses and the atypicality of the cells.

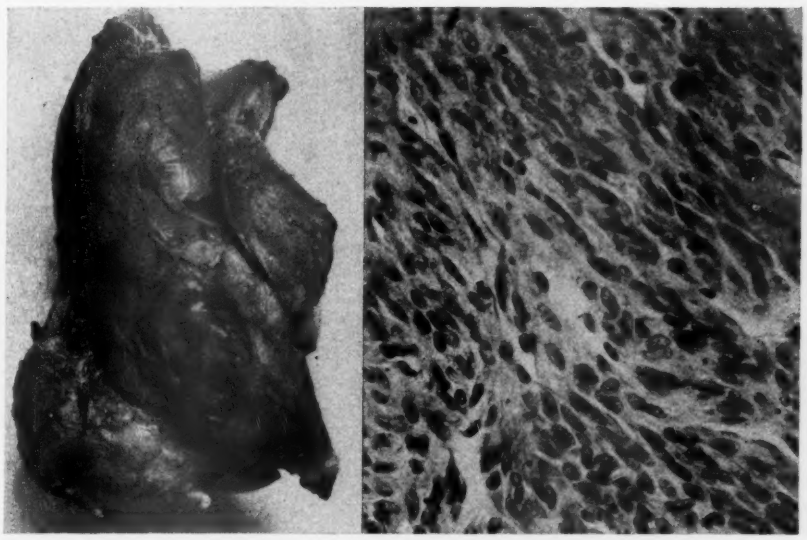

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Fig. 4. Synovioma, invading os calcis. A, gross photograph of large, sausage-shaped mass under long arch of foot and invading os calcis. B, photomicrograph showing cellular structure of tumor. Undifferentiated spindle-shaped endothelial cells in irregular masses.

Temporarily, such patients may be relieved by irradiation, and it is held by some observers that early amputation may result in permanent relief. However, in our experience and in carefully combing the literature, no form of therapy seems to be of lasting benefit. It is our impression that conservatism is preferable, to avoid the shock of radical surgery which offers so little for any appreciable length of time.

Finally, in the group of tumors generally conceded as arising from endothelial cells should be mentioned the synovioma, a tumor ordinarily arising from the synovial lining of joint cavities, bursae and tendon sheaths. This is a tumor which is probably more common than is generally realized and might readily be mistaken by the inexperienced pathologist for a fibrous tissue tumor. Here again, biopsy examination seems to be of particular value as the great majority of these tumors are extremely slow in their development and if completely excised should not recur. The difficulty in the majority of cases lies in the technical difficulty of radical excision which may only be accomplished by actual amputation. If excision is not complete, then the tumor may be expected to recur with increasing malignancy and ultimately to metastasize to the lungs and cause the death of the patient.

VIII. Tumors of Bone. The tumors of bone have been so thoroughly discussed in the literature in recent years, and have been so adequately reviewed in Geschichter and Copeland's monograph, "Tumors of Bone," that it would seem to serve no particular purpose to explore this field in detail. Rather, we are inclined to review the major varieties of bone tumors in relation to their differential diagnosis from other conditions with which they may readily be confused clinically, roentgenologically and even pathologically.

1. *Benign Bone Tumors.* Of the benign tumors of bone, we need only mention the fact that osteomata and chondromata may be encountered occasionally. Their chief interest lies in their differentiation from inflammatory exostoses, enchondroses and from their malignant counterparts. This may only be possible by very careful correlative studies by clinician, radiologist and pathologist.

More important than these tumors is the frequently encountered benign giant cell tumor. Its differentiation from chondrosarcoma, from osteitis fibrosa cystica and even from osteomyelitis and Hand-Christian-Schüller disease may at times present considerable difficulty. It has been our experience that the majority of these lesions may be recognized by history, clinical examination and *x*-ray studies, but that in the smaller group of somewhat indeterminate cases, biopsy is an entirely innocent procedure and leads to the correct diagnosis, which obviously may materially influence the form of therapy to be carried out. Here as in the previous instances cited, the closest possible coöperation between the clinician, radiologist and pathologist is most essential.

Indeed, one might carry this thought a step further and call to the reader's attention the not infrequent necessity of clinical pathologic examinations, especially blood chemistry studies relating to calcium balance, in an effort to determine whether any given case showing osteolytic changes such as are seen in giant cell tumor of bone may have an underlying parathyroid dysfunctional basis. The obvious importance of hematologic studies, and even of urinalysis, in these cases is likewise not to be overlooked nor disregarded. The finding of Bence-Jones protein in the urine may be the necessary clue to the establishment of a correct diagnosis of myeloma in a previously unsuspected case. Changes in the Schilling index, even when the total white count is not abnormally elevated, may in turn suggest that the process is an infectious, inflammatory one of a low grade and again lead to proper diagnosis and treatment.

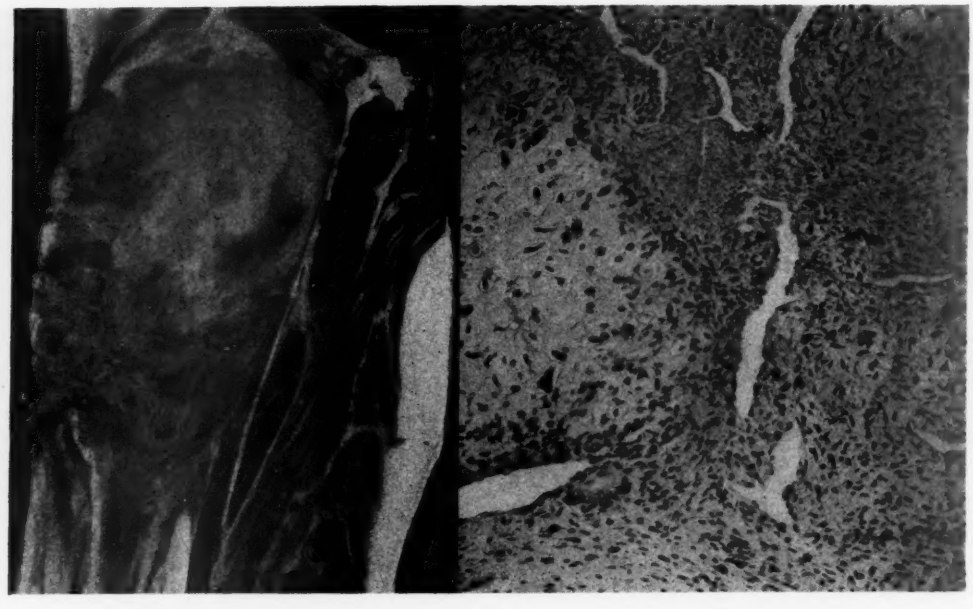

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Fig. 5. Osteogenic sarcoma of femur. A, gross sagittal section of chondromyxomatous type of osteogenic sarcoma of femur, destroying bone, but with marked chondroplasia. B, photomicrograph showing cartilaginous nature of tumor at left, and marked anaplasia of cells at right.

2. *Malignant Bone Tumors.* Of the malignant forms of bone tumor, those which primarily arise from the bony or cartilaginous elements of the bones are best included under the generic term of osteogenic sarcoma. There is little occasion to call attention to the comparatively well known features of these lesions in view of the widespread dissemination of knowledge regarding bone tumors in general since the formation of the Bone Tumor Registry by E. A. Codman of Boston, and its sub-

sequent expansion under the American College of Surgeons. The differential diagnosis of osteogenic sarcoma from Ewing's endothelial myeloma or even at times from the benign giant cell tumor may cause considerable difficulty. In general, however, a carefully extracted clinical history and thorough roentgenologic studies should suffice to establish the diagnosis in the majority of cases. It is our belief, however, that a certain proportion of these cases do offer difficulties in clinical diagnosis and, as in the case of the benign giant cell tumors already cited, should be studied in conjunction with the pathologist, and biopsy examination made. It is probably preferable to plan such a biopsy as an immediate frozen section type of study so that the required operative procedure with radical amputation can be carried out as soon as diagnosis is established. While it is our own belief that statistical studies do not reveal any definite increased danger of causing metastasis by such a biopsy procedure followed by an interval before surgery is done, yet one cannot but feel that if such a possibility does exist, then it is more likely to occur in a case of this type where the invasion of the vascular system could most readily occur.

With the early diagnosis of an osteogenic sarcoma, and it is in the early case that biopsy is particularly indicated, statistical studies have shown that there should be nearly a 20 per cent chance of recovery if amputation is done. If the pathologist could impress upon the clinician the importance of thorough study of cases in which the diagnosis of bone disease is even remotely suspected, it is quite possible that these figures of five and ten year cures of osteogenic sarcoma could be materially increased.

In respect to Ewing's endothelial myeloma tumor, again biopsy, either as a puncture aspiration procedure or as a more radical actual excision of tissue, may be the most satisfactory way of establishing the diagnosis in early and atypical cases. The significant factor in the determination of such a diagnosis lies in the totally different prognosis as compared with that of the osteogenic type of sarcoma and in the fact that therapy except under most unusual circumstances should be irradiation rather than surgery to give the patient the best possible opportunity for recovery.

Of the multiple myelomata of the plasma cell type, little need be said. The disease is not confined to the extremities. Indeed, the extremities are often among the last of the skeletal structures to be attacked. The diagnosis is often wholly a radiologic one in conjunction with the clinical findings, but may well be substantially confirmed by clinical pathologic studies of the blood and urine. In this fortunately uncommon group of cases there seems to be little indication for biopsy in order to prove the diagnosis.

Finally, the group of metastatic tumors which invade the skeletal system must be considered very seriously as a diagnostic problem which frequently confronts the pathologist as well as the clinician and radiologist. These tumors are predominantly carcinomatous, arising chiefly from one or another of the glandular organs, notably the breast, prostate and thyroid, and less frequently from the gastrointestinal tract, kidney, adrenal and other organs. In no group of cases is a careful history more important, for what might ordinarily appear to be irrelevant, unimportant facts loom significantly in a review of a case in the establishment of the final diagnosis. As an example, I might cite a case of a woman in her middle forties who had had a small nodule removed from her breast eight years previously. This information was obtained only after a very extensive study of the case had revealed widespread osteolytic lesions in the long bones of the lower extremities. The patient had completely forgotten the incident because at the time she had been told the lesion was benign and had given it no further thought. The roentgenologic findings were atypical in their diffuseness and there was a very marked anemia which led to a wide variety of opinions and a very

intensive therapeutic barrage to overcome what was subsequently shown to be a myelophthisic anemia due to metastatic tumor invasion throughout the skeleton. Upon the insistence of the pathologist, a biopsy from one of the bone lesions was finally obtained and the diagnosis established.

In the same way, so many instances of metastatic carcinoma of the prostate occur without prominent clinical symptoms of prostatic disease, and unless the history is gone into in unusual detail, minor changes in bladder habits may well be overlooked and attention diverted to some totally unrelated condition.

In the further differential diagnosis of bone lesions, I should like to call attention to one group of cases which I believe merits more consideration than has been given it in the past. This is a lesion which affects usually the long bones of the lower extremities, not infrequently involving such bones as the os calcis. It is perhaps best known by the term sclerosing osteitis. It has been our good fortune to have the opportunity, through the coöperation of Dr. John Royal Moore, of studying a series of such cases. Here as in perhaps no other single instance does the final differential diagnosis depend upon biopsy study. The differential diagnosis from bone tumor, particularly osteogenic sarcoma, by *x*-ray, except in the hands of the most experienced radiologists who are familiar with this condition, is almost impossible and has been frequently erroneously reported. I am convinced that a certain number of instances of cured osteogenic sarcomata which have been reported by clinicians and radiologists without the subsequent confirmation of pathologic study represent such cases of sclerosing osteitis. The age incidence is similar, the cases occurring particularly in the younger age group, more frequently in males, and characterized by the usual history of antecedent trauma followed by progressively increasing pain. Clinically the degree of pain is out of proportion to the clinical and radiologic evidence of any bone lesion. This alone should raise the question of diagnosis in the surgeon's mind. Roentgenologically, not infrequently, there is marked thickening of the cortex which may be accompanied by osteogenesis and bone spicule formation.

The disease is probably a form of subacute infection which involves the periosteum and cortex of the bone rather than the medullary canal and becomes sealed off from the medullary canal by the proliferative reaction which closes the entire Haversian system in the area involved. It is this interference with the blood supply and the pressure upon the thickened and elevated periosteum which apparently produce the symptoms. Clinically, relief is obtained by reëstablishing the cortical circulation either by guttering the cortex or by perforating it with multiple adequate drill holes so that new vessel formation can take place. Diagnosis depends in the majority of these cases upon the histologic study of this bone, which shows evidence of hyperplastic sclerosis but not of neoplasia.

Of the other lesions which have been listed in the early part of this report as among those causing difficulty in diagnosis and requiring histologic study by the pathologist, none perhaps needs further detailed comment. It is well, however, to reiterate the difficulties which the clinician may have in arriving at a correct diagnosis in many of these conditions without the coöperative help of the radiologist and pathologist, and to recognize the importance of such combined efforts in improving our methods in diagnosis and treatment for the ultimate benefit of the patient and mankind.

DISTURBANCES OF THE METATARSAL ARCH AND AN AID TO CERTAIN STATIC FOOT CONDITIONS

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DISTURBANCES OF THE METATARSAL ARCH

FOR a long period it was a general conception that nearly every disturbance involving the metatarsal arch was a "Morton's toe." The term "metatarsalgia," meaning pain in the metatarsal region, is a symptom and does not describe the pathologic condition.

In the January, 1876 issue of *The American Journal of the Medical Sciences*, Thomas G. Morton of Philadelphia reported "a peculiar and painful affection of the fourth metatarsal phalangeal articulation" which has since been recognized as Morton's toe or Morton's neuralgia. He wrote "In those cases the pain has been localized in the fourth metatarsal-phalangeal articulation; in several instances it followed an injury of the foot, in others it gradually developed from pressure, while in others there was no recognized cause." In a report covering the histories and treatment of twelve cases, he said: "Of the twelve cases which I have reported, eleven have occurred in females."

Morton ascribed the neuralgia to the peculiar position which the fourth metatarsal-phalangeal articulation bears in relation to that of the fifth, the great mobility of the fifth metatarsal, which by lateral pressure is brought into contact with the fourth, and lastly, the proximity of the digital branches of the external plantar nerve which are, under certain circumstances, liable to be bruised by, or pinched between, the fourth and fifth metatarsals. He attributed the greater incidence in females to the greater delicacy and pliability of the female foot as compared with the male foot, and perhaps in a measure to the prevailing custom, especially with fashionable women, of wearing tight and very narrow shoes. The fifth metatarsal is thus pressed against the head and neck of the fourth. The phalanx of the fifth especially is forced down upon the head of the fourth and its associated phalanx.

The metatarsal arch is a curved structure seen on the side or oblique view of the skeleton, extending from the tarsometatarsal articulations to the end phalanges or at least to the proximal interphalangeal joints.

The skeleton of these parts consists of the metatarsal bases, shafts and heads. The proximal phalanges and sesamoids are accessory structures often affected by metatarsal disturbances. The metatarsophalangeal joints are simple ball and socket joints surrounded by capsules lined with synovial membranes. They are subjected to stress, strain, injury, growth disturbances and infections. The muscles of this region are the plantar and dorsal interossei, the lumbricales and the adductor hallucis. The tendons are the flexors and extensors of the toes, the abductors and adductors, and the peroneus longus. The plantar fascia is an important structure. The interdigital vessels and nerves at times demand special consideration. There are bursae between the metatarsal heads. The skin of the plantar surface of this area is unusually thick.

The functions of the metatarsal regions are to afford stability in locomotion, to permit spring and resilience to the step and to relieve the spine and central nervous system of jars. The transverse arch is highest near the tarso-metatarsal joints, and gradually lowers toward the metatarsal heads. The arch protects the nerves, vessels, muscles, tendons and ligaments from injury.

The transverse arch is maintained by the transversely directed dorsal, plantar and interosseous ligaments. The obliquely directed peroneus longus tendon and to some extent the expansion of the tibialis posticus tendon, afford some support. When the transverse arch is properly maintained, the anterior pillar of the longitudinal arch rests on the heads of the first and fourth metatarsal bones only; that of the fifth also presses on the ground in many cases, especially when more weight is borne on the foot. If the transverse arch yields, the heads of the intervening metatarsal bones receive undue pressure and periostitis and callosities develop under them. The lumbricales and interossei muscles fix the toes to the ground in walking and are important sustainers of the arch. When these groups of muscles are paralyzed or weakened, the toes assume a position of "claw toe" and the normal gait is interfered with. If the toes are forced to assume a position of clawing by any cause, such as improper shoes, these two groups of muscles are unable to function properly, and the unopposed action of the extensor muscles aggravates the clawing and depresses the metatarsal heads. The transverse head of the adductor hallucis approximates all the toes, thereby increasing the curve of the transverse arch. The metatarsal arch is curved in two directions, laterally and anteroposteriorly. The structure formed by the metatarsal heads is the true transverse arch.

Etiology. The etiology of metatarsal disturbances is varied. Very common in adult patients, metatarsalgia is comparatively infrequent in childhood, during which period many of the cases are due to osteochondritis, a condition described by Freiberg as infraction of the metatarsal head. I have treated at least twenty such cases. The cause is thought to be trauma to growing epiphyses, which interferes with normal local circulation and growth.

Metatarsal troubles are more common in the female, undoubtedly the result of improper shoes and incorrect shoe fitting. Short stockings or the forceful pulling of stockings are additional factors. Heredity may be important, especially in arthritic and pes cavus cases.

Arthritis is an important cause of metatarsalgia. Infections of various types contribute a fair share of these cases. The infection may be local or focal such as infected teeth, tonsils, sinuses and abdominal or pelvic structures. Toxemia as from pregnancy or from an infection like influenza, may be a causative factor. Static disturbances, such as prolonged standing on hard floors or other surfaces, predispose to metatarsal disturbances. Traumas of various sorts are important, among which may be mentioned the sprain or strain as seen in the chauffeur's foot or in the dancer's foot, especially while toe dancing. The trauma from shoes has been mentioned. Injury by falling objects or being stepped on by another person or by an animal may cause metatarsalgia.

Inflammation of the metatarsal bursae produces metatarsalgia. Roberts describes a type of bursitis which gives rise to a disabling soreness sometimes confined to the ball of the foot, sometimes extending upward and backward, and sometimes accompanied by puffiness of the adjacent soft tissues. The pain subsides when the foot is at rest and recurs when standing or walking is resumed. Acute twinges of pain occur in stepping on an uneven surface such as cobblestones or streetcar tracks because sudden pressure is brought upon the distended sacs. Royle also described metatarsal bursitis. Hertzler recalls that there are in the region of the metatarsophalangeal articulation three sets of bursae: (1) the intertarsophalangeal, the largest and those usually involved; (2) the bursae below the heads of the metatarsal bones; and (3) those about the tendons in this region. Hertzler believes that some of these cases are examples of "anterior plantar bursitis" (metatarsal neuralgia).

Subsequent writers have followed Morton's conclusions with serious doubt.

The more frequent occurrence of the pain about the fourth metatarsal head was ascribed to the fact that the fifth metatarsal bone being shorter allowed its head to impinge on the nerve. The removal of the head of the bone was supposed to relieve this impingement.

Hertzler calls attention to the fact that in the removal of the metatarsal head the bursae lying beside it also were removed, He believes that the removal of the bursae alone might effect a cure.

I have seen a nurse who developed metatarsalgia following the accidental shooting off of all her toes. I have also seen a surgeon who had metatarsalgia following a septic infection of the metatarsal region, as a result of the piercing of his shoe by an infected scalpel which dropped during an operation. Amputation, bunion operations, and hammer toe operations are frequently followed by metatarsalgia, often, however, present but unrecognized before the operation. Fractures, dislocations and thermal and chemical burns may cause metatarsalgia. Spastic paralysis, plantar fascitis, paralgia hyperesthetica are causes of metatarsalgia; also the following conditions:

Fig. 1. Feet of primates, man and monkeys. (Courtesy The American Museum of Natural History, New York.)

pes cavus that is independent of, or coincident with, spina bifida, sometimes appearing at puberty; circulatory lesions such as endarteritis; thrombo-angiitis obliterans; Raynaud's disease; causalgia; frostbite, chilblains; trench foot; and soft corns. I have seen several cases of incomplete amputation of the toes which resulted in metatarsalgia.

Pathology. The pathologic changes are anatomic or mechanical plus infectious or toxic factors. The anatomic considerations are depression or inversion of the arch which normally is convex above. There results pressure on the interdigital nerves and relaxation of the capsules and ligaments. Periostitis of the metatarsal bone may be found. Bursitis was described above. Papillomas and soft corns, usually between the fourth and fifth toes, are common. The infectious factor is similar to that in any other joint.

Symptoms. The symptoms of metatarsal depression are pain, rigidity and at times spasm and contractures of the extensor muscles. The physical conditions of metatarsal depression are the inversion of the arch, callus formation, sensitiveness and tenderness which may be due to periostitis of the metatarsal bones. Every schoolboy knows that if he can grasp another boy's hand, depress the knuckles and exert lateral compression, he can cause pain. An analogous condition is found in a depressed metatarsal arch.

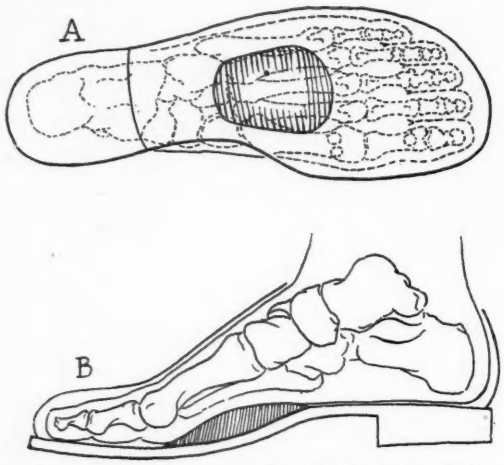

FIG. 2. A, position of bevelled felt pad for metatarsal arch with relation to the metatarsal bones. B, position of pad in shoe.

Diagnosis. Roentgenograms, although not always necessary in making a diagnosis, should be made routinely. A good history and careful examination are usually more valuable. Lateral roentgenograms reveal the depression on lateral view; and may show bunions, "bunionettes" (exostoses of the fifth metatarsal heads), the position and integrity of the sesamoids, and occasionally, metatarsophalangeal osteochondritis.

Deutschlander's disease affects usually the shafts of the second or third metatarsals. It appears to have a spontaneous origin and the findings may be divided into three stages: a period of about two months during which there is a localized tender spot but no roentgenographic changes; a second period during the fourth month when there is new bone formation, and a third period or stage of cure with diminution of callus. Peremans believes that Deutschlander's disease is due to a fracture between the middle and the lower third of the metatarsals due to improper statics and may occur spontaneously in a bone previously unaffected.

Prognosis. The prognosis depends on the pathologic condition and the coöperation of the patient in carrying out proper treatment.

Treatment. The treatment of the usual type of metatarsalgia consists of local and general measures; the latter being removal of foci of infection and the correction of metabolic, hygienic and dietetic disturbances. The local treatment consists of relief from inflammation or irritation, proper shoes and shoeing, metatarsal support, and the physiologic restoration of power of the supporting structures of the arch. Relief from irritation and inflammation may be accomplished by rest and non-weight-bearing. In the severe cases rest in bed is necessary, with the application of an anodyne lotion used in conjunction with fomentations and elevation of the feet.

℞

Tinct. opii	30
Liq. plumbi subacet. dil	40
Phenolis ½ per cent	50
Ext. hamaemelidis	60

M. et. ft. lotio
Sig. Externally as directed.

Compartment A
1. Apply four layers of gauze over entire foot and ankle.
2. Saturate the gauze with the lotion after the bottle has been well shaken.
3. Apply oiled muslin, silk or rubber sheeting.

Compartment B
4. Apply four layers of flannel or wool wrung out of hot water.
5. Apply oiled muslin, silk or rubber sheeting.

Compartment C
6. Add hot water bottle to the side of the dressings.
7. Cover everything with a turkish towel.
8. Elevate leg and foot.
9. Add more lotion twice daily.
10. Keep water bottles hot continually from 9 A.M. until 9 P.M.
11. From 9 P.M. until 9 A.M. use an anodyne ointment plus dry heat.

Shoes must be of straight last, round toe, medium width shank and moderate height heel. The flexibility or rigidity of the shank depends upon an accompanying disturbance of the longitudinal arch. The fitting of the shoe is very important. Custom made shoes are often too short. The shoe may be modified by the addition or insertion of a metatarsal bar, crescent or preferably a comma bar. Properly shaped and bevelled felt pads are inserted in the shoe to support the depressed structures. The pads may be applied directly to the foot temporarily, secured by means of a resinous glue and strips of adhesive plaster or by means of a simple elastic metatarsal cuff, which in itself has some value in supporting the arch laterally. A laced leather cuff is preferred by some. An adhesive plaster compression band around the waist of the foot often affords considerable temporary relief.

The felt pad is usually inserted directly into the shoe, being secured by means of glue. An insole is not essential. Because it is not physiologic to compress the delicate foot muscles between the rigid bones above and a rigid object below, I practically never use a metal plate to support a depressed metatarsal arch, depending entirely on the resilient support of the felt pad. Sponge rubber may be used. The patient's hose should be long enough and must not be drawn too tightly. Massage of the feet twice daily with an anodyne ointment is beneficial. Contrast foot baths afford the feet a valuable tonic.

Special exercises are of the greatest value in increasing the power of the supporting structures and the flexibility of the metatarsal arch. Numerous exercises have been described and recommended. The following have been found of much value (each exercise is done with the bare feet twice daily).

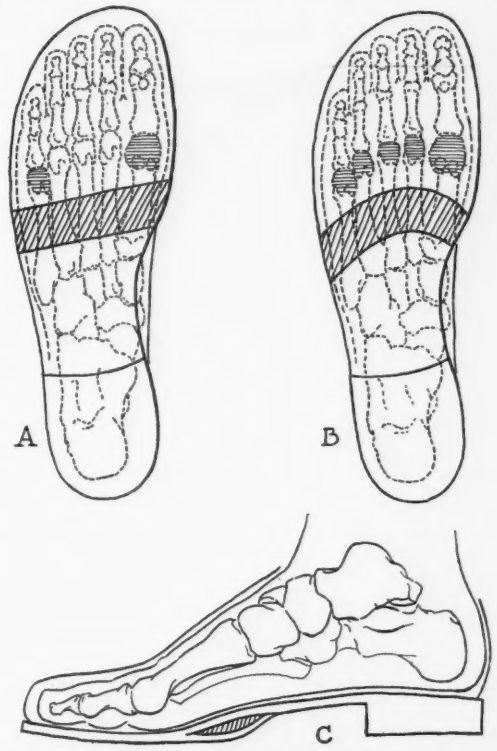

Fig. 3. A, position of bevelled leather metatarsal bar usually 3/8 inch thick and 1 inch wide. B, position of metatarsal crescent in relation to heads of metatarsal bones. C, side view of shoe and foot with cleat in position.

1. *Door Stop Exercise.* Two old fashioned door stops obtainable at the hardware section of a 5 and 10 cent store, are prepared for use by removal of the rubber tips with a pair of nippers. They are then screwed into a board about 14 inches long, 8 inches wide and 2 inches thick. The centers of the door stops should be 6 inches apart. A heel rest the same height as the door stops (2 3/8 inches) is added.

The board is placed on the floor, and the patient sits on a chair in front of it. Each foot is placed with heel on the heel rest and

metatarsal arch on a doorstop, with very slight pressure just behind the metatarsal heads or calluses. On the count of 1, the

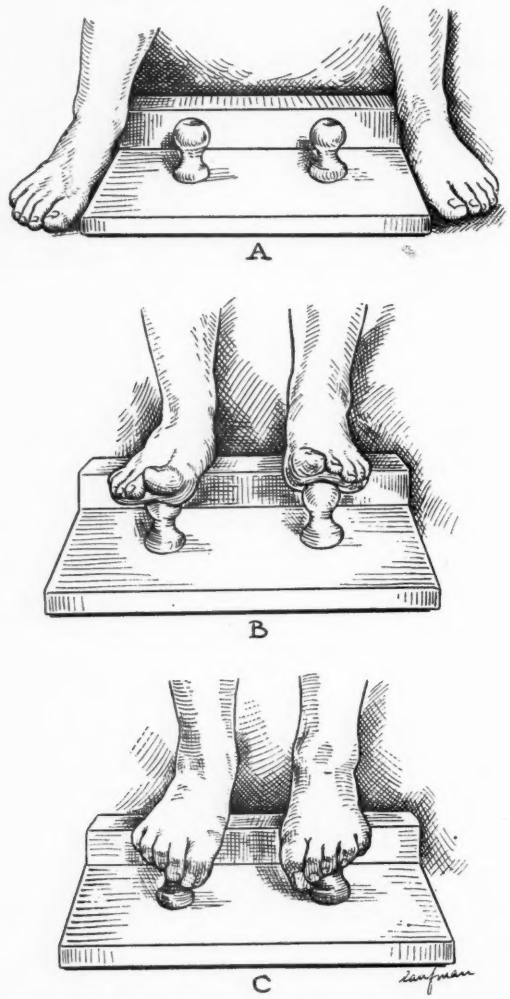

Fig. 4. Doorstop board and exercise for metatarsal arch. No ankle valgus is permissible.

toes are forcibly curled down, and on the count of 2 they are allowed to relax slowly. This is continued until one has counted 200. (This number should be attained gradually.)

2. *Towel Exercise.* The patient sits on a chair. A large hand towel is spread on the carpet, with the narrow edge facing the patient. The feet are placed so that the posterior half of each foot is on the towel. The towel is grasped with the toes of one foot, then with the toes of the other. As the toes of one foot grasp, those of the other relax. This is carried out until the entire towel is under the feet.

3. *Golf Ball Exercise.* A golf ball is placed on the rug and rolled under the metatarsal arch for one minute. Then it is picked up with the toes of one foot and placed under the toes of the other foot, and the exercise is repeated for another minute. The patient alternates in this manner six times.

4. *Rubber Ball Exercise.* A small rubber ball may be used as substitute for the golf ball.

5. *Marble Exercise.* Marbles of various sizes are placed on a rug. The patient sits on a chair and picks them up with the toes.

6. *Pencil Exercise.* A round pencil is placed on a hard floor and by means of the toes, curled downward, the patient pushes and pulls the pencil around the floor with short, quick movements.

Massage. This should be done for five minutes each morning and night. It is desirable that the patient lie down while another massages his feet. Do not rub, but use a deep rotatory movement.

Contrast Baths. Obtain two buckets, each large enough to contain both feet. Fill bucket No. 1 about two-thirds full of warm water, and bucket No. 2 two-thirds full of cool water. Sit alongside of the buckets, place both feet in the warm water for exactly one minute. Remove feet and place in the cool water for exactly one minute. Alternate in this manner for ten minutes, i.e., five in each bucket. This routine is to be carried out twice daily.

Contrast Sprays. Sit on the side of the bath tub and spray both feet with warm water for exactly one minute; then with cool water for exactly one minute. Alternate in this manner for ten minutes, twice daily.

When massage, exercises and contrast baths are prescribed, they should be carried out in the following order:

Mornings: massage, exercises, contrast baths.

Nights: contrast baths, exercises, massage.

Inductotherm, negative galvanism and sinusoidal current are helpful adjuvants in

the treatment. Plaster of Paris casts are occasionally indicated. Less frequently operation is necessary. The various operations in this region are tenotomy, tenodesis and tendon transplantations such as the Jones or Sherman operations. Hoffman's operation, consisting of removal of the metatarsal heads, should be reserved for extreme cases. Murk Jansen tenotomized the transverse head of the adductor hallucis with excellent results. Spitzy restored the metatarsal arch by a silk suspension ligature passed around the heads of the first and the fourth metatarsal bones. Arthrodesis and arthroplasty of the four outer metatarsal joints is rarely indicated.

HYPERMOBILITY OF THE FIRST METATARSAL BONE

D. J. Morton describes a condition of hypermobility of the first metatarsal bone which is due to unusually free motion in the joint between the inner cuneiform and scaphoid bones, and between the inner and middle cuneiforms. The resulting instability of the inner anterior pillar affects both the metatarsal portion, and the longitudinal arch of the foot.

Physiologic hypertrophy of the second metatarsal bone is the most notable structural feature. Metatarsalgic symptoms are more frequent than symptoms of longitudinal arch strain.

D. J. Morton believes that the term "anterior metatarsal arch" is an anatomic misnomer. The ball of the foot assumes transversely a more or less concave form when in a passive state; but in a weight-bearing foot the heads of all the metatarsal bones lie in a single horizontal plane—each one having direct contact with the ground or supporting surface. In other words, there is no real arched conformation maintained in this part.

D. J. Morton states that the clinical word "metatarsalgia" is commonly used interchangeably with the term "depressed anterior arches." But since the heads of the metatarsal bones lie on the same horizontal plane in their functional relationship, and because of the usual solidity of the supporting surface, there can be no actual depression of the middle ones.

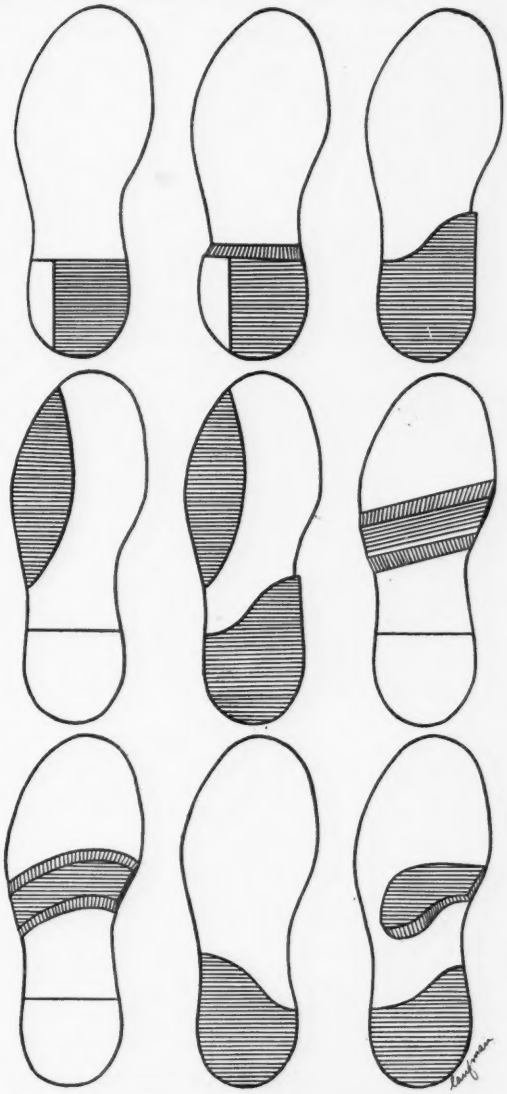

Fig. 5. Various types of shoe modifications or adjustments.

Hypermobility has been observed to be a very common factor in the "weak feet" of children.

Some cases of hypermobility are suitable subjects for either the flat-foot operation described by Miller or that of Morton. In the latter method, arthrodesis is performed between the inner and middle cuneiform bones, and between these two bones and the scaphoid.

Dudley J. Morton reported thirty-four cases which presented different degrees of

"arrested" development of the first metatarsal bone, attended with symptoms suggesting the ordinary type of metatarsalgia, or having a definite history of "Morton's toe." Twenty-eight of these patients were adult females. In twenty-nine of the thirty-four cases the symptoms have been of the milder metatarsalgic character, only five giving histories of acute paroxysms of pain.

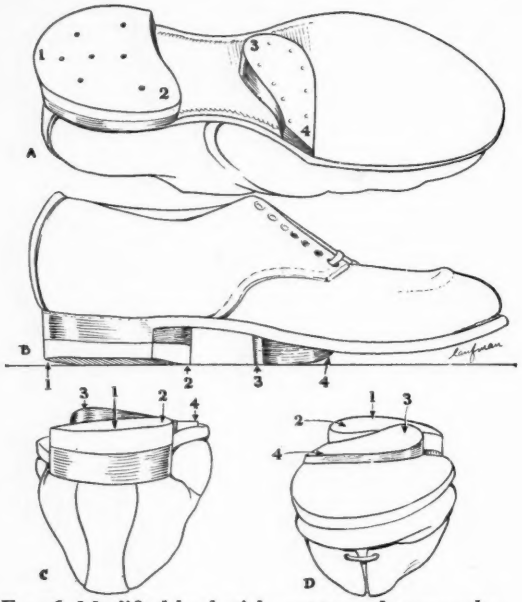

Fig. 6. Modified heel with metatarsal comma bar. A, oblique view of sole of shoe. B, side view of sole of shoe. C, rear view of heel and sole. D, front view of sole and heel.

METATARSUS ATAVICUS

A painful disorder of the anterior portion of the foot, to which the term "metatarsus atavicus" has been applied by Dudley J. Morton, presents two characteristic signs. The first is a morphologic one, manifested in the unusual shortness of the first metatarsal bone as compared with the length of the second. The other is the clinical symptom of tenderness elicited by deep pressure on the sole of the foot in the region of the second metatarsocuneiform joint. The head of the second metatarsal bone is definitely in advance of that of the first. Associated with the more extended position of the second metatarsal bone, there is an increase in the transverse diameter of its shaft and in the thickness of its dense cortical walls. It presents a marked contrast to the lateral slenderness of the three outer metatarsal bones, and may even exceed the breadth of the first metatarsal.

The most frequent complaint is indefinite discomfort or pain in the forepart of the foot, brought on by an unusual amount of active function such as walking, dancing, tennis playing, or by prolonged standing. One of the earliest and most transient symptons is a burning sensation in the ball of the foot, following an excessive amount of foot function. This sensation is later replaced by pain of a sharper, more acute character, or by dull aching pain. In some cases, the pain is of a sudden, spasmodic character located usually about the head of the third or fourth metatarsal bones, extending into one or the other of the toes and sometimes up the leg.

When the foot is viewed dorsally, the great toe is often shorter than the second, although this difference is sometimes obscured by an habitual flexion of the distal phalanx of the latter. Plantarly, the ball of the great toe appears set well back on the foot, especially when compared with the forward extension of the fleshy area beneath the heads of the second and third metatarsals. In a majority of the cases a callosity is located under the head of the second metatarsal bone.

The characteristic clinical sign is the tenderness which can be recognized on deep palpation of the sole of the foot, about the juncture of the middle cuneiform bone with the base of the second metatarsal.

METATARSAL EQUINUS

Metatarsal equinus is a term used by Hoke to describe all deformities of the feet in which there is an equinus or cavus element. They are painful feet. A small percentage of them need to be operated on. In metatarsal equinus the anterior ends of the metatarsals are pitched down, and are found just beneath the skin in the ball of the foot. Calluses form beneath them. The ball is painful from the digging of the

anterior ends of these bones down into the ball of the foot when standing or walking. There is also an enlargement of the inferior part of the anterior end of the metatarsal bone. This becomes an added source of pain because of pressure.

The basis of Hoke's operation has been to remove the anterior two-thirds of the metatarsal bone, after subperiosteal dissection, operate on the bone while it is out of the wound and immediately reimplant it in its periosteal bed, setting it in a way so that a normal mechanical and anatomic situation exists thereafter. He advises taking the bones out, shortening them a little, pitching the toes down, and reimplanting the bones turned upside down. In all, forty-one metatarsal bones have been removed, remodeled and reimplanted.

Description of Operation. From one to three bones can be operated upon at each sitting. The incision is made on the dorsum of the foot. If one bone is to be operated on the incision is over the shaft. If two are to be operated on, the skin incision may be made between the two. After the incision is made the tendons are released by gentle dissection and retracted. By deep pressure of the blunt end of an instrument the course of the metatarsal bone is determined. A deeper incision is then made down on the bone through periosteum throughout its whole length, and when the toe is reached, the incision is curved a little to one side, to avoid cutting the dorsal tendon going to the toe. The periosteum is then dissected from the metatarsal. The bone is osteotomized near the posterior end, using either a thin, narrow osteotome or, preferably, a small bone cutting forceps. The metatarsal bone is then grasped with a sharp pair of forceps and by rotating it right and left, the capsule is entirely cut loose at the metatarsophalangeal joint. The metatarsal bone is then removed. A little is cut off the posterior end of the removed part so that it will fit accurately in length when it is replaced and the dislocated toe dropped down into its normal position. It is reimplanted turned upside down. When the bone is turned upside down, the bottom part of the anterior end, which is enlarged, is now the upper part, and this is cut off with bone cutting forceps. A small tibial graft is used as an intermedullary graft in pinning the bone ends together at the site of the osteotomy. The cavity in the sole of the foot beneath the anterior ends of the metatarsals is closed by sutures.

It is often advisable to arthrodese the first interphalangeal joint of the toe. The operation makes it possible to relieve two extremely painful disturbances of the metatarsal part of the human foot—extreme hallux valgus and metatarsal equinus, and the affliction that is associated with walking and weight bearing with and without dislocation of the toes. Experience suggests also that this is a method of relieving the disabilities resulting from fractures and crush injuries of the anterior part of the foot that have healed in a way to produce pressure-pain from weight bearing.

MARCH FOOT

March foot is a subacute painful affection of the forepart of the foot, occurring chiefly about the shafts of the metatarsals and the surrounding soft parts. It develops insidiously with slowly increasing pain, which at first arises after prolonged excessive effort, later after ordinary exercise, and ultimately becomes continuous and incapacitates its victim.

March foot is often associated with an insidious spontaneous fracture of one of the metatarsal bones. According to Speed and Blake, the condition has been recognized for many years, especially by foreign military surgeons, who frequently encountered it among their troops after strenuous duties or long marches.

The history and clinical appearance are typical. A soldier after a long march, or a civilian who has been subjected to excessive foot strain, complains of pain in the forefoot and tenderness over the anterior portion of the second or third metatarsal bones. This is not sufficient to disable him

and he continues with his duties only to have the disability increase. After a few days a swelling is noticed involving the dorsal surface of the forefoot. The condition improves with rest, but resumption of activity aggravates the lesion.

Dodd believes that march foot is an "autotraumatic" complication of subacute flat foot occurring in architecturally weak feet. Muscular spasm and fatigue alternate, and as the latter supervenes the ligaments of the foot are gradually stretched, permitting direct trauma to the bony skeleton of the foot. These shocks affect the weakest bones first, i.e., the slender, resilient metatarsals. The second metatarsal is most commonly affected, then the third.

The majority of cases occur in soldiers carrying full packs on active service although civilians engaged in similar heavy occupations are affected. Women with arduous standing and weight-carrying work (waitresses, shop assistants and nurses) also develop the condition. Narvi believes that overloading causes stasis and thrombosis in the soft parts surrounding the bone and thereby interferes with the nutrition of the periosteum. The consequent swelling can be observed clinically as a painful mass on the dorsum of the foot and on the tibia. The roentgenograms of the metatarsal bones reveal a fracture line. The tibia first shows fissures penetrating deeply into the bone and an opacity of the bone structure; later, a callus formation and an induration of the bone appear.

Speed and Blake obtained complete series of roentgenograms in several cases, starting before there was any evidence of bone changes and following them through the various stages of early periosteal proliferation, the appearance of the fracture line, the formation of excessive callus, the healing of the fracture with contraction of the callus and eventual restoration of the apparently normal bone. The normal sequence of changes shown by the roentgenograms are as follows: (1) If taken very soon after onset of symptoms, the bones will be found to be entirely normal and only swelling of soft tissues will be noted. (2) After one to three weeks there will be a little periosteal fuzziness at the site of the beginning fracture; very close observation may show a minute line of fracture. Occasionally the fracture appears before the periosteal reaction is seen. (3) A little later the periosteal shadow becomes more distinct and circumscribed and it will be noted that this callus is overabundant for the size of the bone involved and the size of the fracture. At this time the fracture usually can be seen distinctly and it will be found to have an irregular outline. (4) The fracture next shows signs of union. The callus is more dense and well circumscribed into a spindle shape. At this stage and in the preceding one, this condition has been mistaken for sarcoma which it simulates to some extent. (5) Films taken six months later will show solid union with absorption of the excess callus. The shaft will appear normal except for a small amount of residual cortical thickening.

The differential diagnoses suggested by Dodd are subacute flat foot, tenosynovitis, spasm of muscles, periostitis, synovitis, arthritis, rheumatism and finally fracture with callus formation. Recognition of the prodromal symptoms before fracture has occurred, is important, according to Speed and Blake because at this time the production of the fracture may be prevented by proper prophylactic measures. With rest, hot applications and relief from weight bearing, the condition may be arrested during the stage of preliminary swelling and the foot return to normal after a week or ten days. Toe exercises to restore the flexibility of the anterior metatarsal arch and a proper arch support or strapping of the forefoot should be employed when walking is resumed. For those patients who cannot comply with the period of complete rest because of economic reasons, strapping of the forefoot gives the most relief. The average disability, where fracture has occurred, is from four to eight weeks. Although suffering varying degrees of pain, very few patients will give up their work

but will continue to limp about, satisfied with the partial relief afforded by the strapping and arch supports.

Treatment recommended by Dodd consists in rest in bed until the pain and edema subside, with complete immobilization of the foot or feet by plaster, which is applied to maintain a dorsiflexed and an inverted position with a well moulded arch. If necessary, manipulation of the feet under anesthesia into this overcorrected position is advisable. With the subsidence of pain, patients get up and are carefully fitted with heavy shoes or boots which adequately support the feet. This footwear is adjusted with inside wedges to the heel and sole, metatarsal bars, or even an outside iron with an inside T-strap, if necessary.

JUVENILE DEFORMING METATARSOPHALANGEAL OSTEOCHONDRITIS

(Freiberg's Infraction of the Metatarsal Head)

This lesion was first described by Freiberg in 1913. He saw his first case in 1903, but his paper reporting six cases did not appear until 1914. Köhler described the condition in 1915, and in 1920 reported five cases. The number of cases reported to date is sixty-three. The two cases reported by myself bring the total number to sixty-five. The condition is much more common than I formerly believed, and I have seen at least twenty cases. Skillern called it an "egg-shell" fracture. On the assumption that it is analogous to similar conditions in other regions, especially in the hip, I added the terms metatarsal epiphysitis, metatarsal "flat-head" or osteochondritis deformans metatarso-juvenilis. A more descriptive term is juvenile deforming metatarsophalangeal osteochondritis.

I believe the etiology is similar to that of Legg-Calvé-Perthes, disease, Osgood-Schlatter's disease, Köhler's disease of the tarsal scaphoid, calcaneal apophysitis and Scheuermann's vertebral epiphysitis, all of which may be due to trauma affecting bone and cartilage during a period of unusual growth. The important factors are: (1) trauma; (2) circulation; and (3) infection.

Freiberg believes that trauma is the cause, and states the mechanism of the injury as follows: Under normal circumstances, the second metatarsal bone is slightly longer than the first. In the presence of diminished power of toe flexion, especially of the great toe, the forcible impact of the ball of the foot against the ground, not sufficiently guarded by the flexor power of the toes, will cause the distal end of the second metatarsal to bear the brunt of the blow. All of his six reported cases were due to trauma, especially while playing tennis. Campbell emphasizes that sudden jumping on the ball of the foot with the toes dorsiflexed throws the heads of the metatarsals downward. He finds basketball, tennis and running upstairs to be the chief causes. Two of Painter's cases were due to baseball injuries. Skillern's patient merely stubbed her toe.

Alberti offers the following explanation: The second toe is longer than the others, and the head of the second metatarsal is the chief support of the foot; therefore it is subject to greater trauma. He is of the opinion that the lesion is first an osteochondritis, and then a chronic arthritis.

Axhausen is opposed to the theory of a traumatic origin, and believes that the lesion is due to an embolic obstruction of the corresponding epiphyseal and end-artery by tuberculous fragments or fragments with weakly virulent pyogenic cocci. The distal thickening of the shaft is explained by simultaneous emboli in the metaphyseal arterial branches, as a result of which inflammation of the bone develops. The local process with secondary arthritis deformans is similar to the formation of free osteocartilaginous bodies with secondary arthritis deformans in the other joints in which a traumatic etiology has been established.

It occurs especially during adolescence. Union of the metatarsal diaphysis and

epiphysis occurs between the eighteenth and twentieth years, and of the phalangeal structures, about the eighteenth year. It is possible that in the adult patients, the condition was present but unrecognized earlier.

All of Freiberg's cases were unilateral. One of Fischer's cases was bilateral. One of Campbell's cases was bilateral, affecting the third toe of the left, and the second toe of the right foot. All of Freiberg's six cases were of the second metatarsal. In one of Campbell's patients the third metatarsal was affected.

Pathology, Embryology and Anatomy. The metatarsal bones are each ossified from two centers; one for the body and one for the head, of the second, third, fourth and fifth metatarsals. The first metatarsal has one center for the body and one for its base. Ossification begins in the center of the body.

The gross pathologic changes consist of flattening of the metatarsal head, with broadening of the neck and distal portion of the shaft and irregularity of the epiphyseal line. In three of Freiberg's cases there were loose bodies.

Axhausen found, on histologic study of two resected specimens, an epiphyseal wedge-shaped necrosis with corresponding reparative processes. Under local anesthesia, Unger resected the metatarsal head in one case. He found the head split, the joint capsule dense, the epiphysis soft and the marrow reddish gray. Valentin's case showed microscopically that the cartilage and, in some places, the perichondrium were rich in cells. There were no marked signs of inflammation. In the metatarsal head that Campbell resected, no degenerative changes were found.

Symptoms and Roentgen Ray Findings. There is a uniform complaint of pain referred to the region of the affected metatarsal head. Swelling is usually present. It is due to exudate. No marked increase of joint tension is demonstrable. There is sharply circumscribed sensitiveness to pressure over the metatarsal head and the metatarsophalangeal joint. Abnormal local temperature is unusual. Definite limitation of motion with muscle spasm is present. Abscess formation has not occurred in the cases reported.

To the Roentgen ray must go the credit for recognition of this condition. The findings are characteristic. They are: (1) flattening of the metatarsal head; (2) broadening of the neck and distal portion of the shaft; (3) irregularity of the epiphyseal line; (4) widening of the metatarsophalangeal joint space; (5) diminished cupping of articular surface of proximal phalanx; and (6) occasional line of incomplete fracture without displacement. Valentin, Axhausen and Liek found areas of sequestration similar to those observed in both cases of my report. In view of the fact that metatarsalgia is relatively uncommon in childhood, it is advisable to have roentgenograms made of both feet of every child who has a persistent metatarsalgia. It is possible that the first film will be negative and that the examination should be repeated. Occasional roentgenograms should be made of proved cases in order to check up on the progress of the condition.

The differential diagnosis rests between Morton's metatarsalgia, Deutschlander's metatarsal periostitis, fracture, dislocation, syphilis and arthritis of childhood, viz., Poncet's or Still's disease. In the condition described by Deutschlander, there is local tenderness at the junction of the middle and distal thirds of the metatarsal shaft, and Roentgen ray examination reveals evidence of periostitis. It is a subacute inflammatory periostitis.

If recognized early, and if proper treatment is instituted, the prognosis is excellent.

The course is short, lasting a few weeks. Recurrences have occurred after non-operative treatment, and all the cases in which operation has been performed are reported as cured.

Treatment. The treatment consists of absolute relief of the affected foot from weight bearing by means of crutches and a block under the heel and sole of the shoe of the opposite foot. The foot should be

immobilized in a plaster cast with a small, beveled felt pad applied just back of the metatarsal heads. As the cast sets, pressure is applied to build up the metatarsal arch.

When all symptoms have disappeared, a proper shoe is prescribed. This should be a straight last, round toe, medium shank shoe into which is inserted a felt pad for the transverse arch.

A metatarsal bar may be used, and the entire leather heel should be removed and a low rubber heel applied. A duralumin or other metal plate made over a corrected plaster cast may be used temporarily. Physical therapy, heliotherapy, hyperemia and hydrotherapy are indicated after the cast is removed. Baking, gentle massage and passive and active movements with contrast baths hasten recovery. Special exercises for the metatarsal arch are performed over a round doorstop screwed to a board. In cases in which the roentgenogram shows loose bodies, arthrotomy is advised.

AN AID TO CERTAIN STATIC FOOT CONDITIONS

As a supplement to my several articles on static foot conditions, especially the one that appeared in the *Journal of Bone and Joint Surgery*, July, 1930, I am presenting a modification of shoes that has a distinct value in a large group of static foot and ankle complaints.

Every orthopedic surgeon has used the original types or has modified them himself.

Sir Robert Jones describes the Crooks long heel and the bar behind the metatarsal tread. He said, "A simple and easy way of relieving the nerve from the pressure from the descended metatarsal head is by putting a leather bar ½ inch or ¾ inch broad across the sole of the boot behind the heads of the metatarsals. As the patient walks, the sole in front of the bar becomes displaced, making a countersunk hollow in the sole so the pressure on the heads of the metatarsal is removed."

The bar was first put on the outside of the sole of the shoe, between the layers of the sole, and finally brought to the outside again. When it is placed between the layers of the sole it acts as a rocker.

The modification which I wish to elaborate on is not my design but the outgrowth of many attempts by various writers. It is a distinct improvement over the combination of the Thomas heel and outer sole wedge or the metatarsal cleat or crescent.

In *Surgical Clinics of North America* (February, 1938), Hauser states, "Case I. A corrective shoe was prescribed with the heel supinated ½ inch and a comma-shaped transverse bar was raised ¼ inch on the outside. The bar extended from behind the head of the 4th metatarsal across the first metatarsal, with an inclined plane directed toward the first metatarsal. . .. Case II. The heel was supinated ⅛ inch and the comma shaped transverse bar was raised ¼ inch on the outer side. . . . Case IV. He was fitted with satisfactory shoes and the usual corrections for pes valgoplanus were carried out. This means a supination heel and pronation of the transverse bar." So far as I know there has been no further description of or any illustration of this modification of shoes.

The objective of many clinicians has been: (1) to supinate the heel and (2) to pronate the forefoot. This can be accomplished by a triad of changes in the ordinary shoes: (1) removal of the metal shank, if present; (2) application of a Thomas heel; and (3) application of a metatarsal comma bar.

When all changes have been made, the shoe must be in perfect balance.

1. The initial bearing surface is indicated (1) on the back of the heel. (Fig. 6.)
2. From (1) the weight is carried to the anteromedial point of the heel.
3. From (2) the weight is shifted to (3) which is the high point on the lateral border of the metatarsal comma bar.
4. From (3) the weight is thrust on (4) which is the low point on the medial border of the metatarsal comma, just back of the big toe joint.

By this progression "foot rhythm" is restored because it supinates the heel and

pronates the forefoot. The "push off" in walking occurs at the big toe joint. (Observe a sprinter for example.)

These modifications fulfill the requirements set up by many orthopedic surgeons and so properly emphasized by Michael Hoke that the three most important muscles and tendons of the foot are given the opportunity, or are compelled to function at their optimum efficiency, viz., anterior tibial; peroneus longus; flexor hallucis longus.

The "comma" may be made of leather or rubber or a combination of both. It may be level or higher laterally or medially, depending upon the individual problem.

Variations of this system may be made as follows:

1. Metatarsal comma bar to correct varus.*

2. Metatarsal comma bar to correct valgus.

3. Metatarsal comma bar to shift weight toward the big toe joint.

4. Metatarsal comma bar to shift weight away from the big toe joint.

In cases of pain in the big toe joint or sesamoiditis the metatarsal comma must be modified to remove pressure from the big toe.

A modified heel and a metatarsal bar can be used with a rigid shank shoe but a rigid shank cannot be used in conjunction with a metatarsal inverted comma.

The patient may alternate with a rigid shank shoe with a metatarsal cleat or crescent.

There are several flexible shank shoes on the market which avoid the necessity of removing the steel shanks of the ordinary shoes.

A large percentage of static foot conditions can be relieved by these modifications.

*After this article had been completed, a paper appeared in the *Surgical Clinics of North America*, February, 1939, in which Hauser discussed muscle imbalance of the foot and presented an illustration of the combination modified heel and the metatarsal comma bar with brief instructions as to measurements.

HAMMER TOE

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HAMMER toe, with the corn-like bursa on its dorsal apex rasping against the toe cap of the shoe and the calloused top of the digit cramped against the sole, is a disability often of greater proportion than such an apparently insignificant deformity would seem to impart. Usually the second toe is affected. The characteristic flexion contracture of the proximal interphalangeal joint more frequently is of congenital origin, but may be acquired through injury or through abuse of the feet by improperly fitted shoes. Clawfoot contracture of the foot in which all the toes are cramped into acute flexion can hardly be classified with hammer toe, nor is the treatment the same. In the typical congenital hammer toe deformity the lateral ligaments and the glenoid ligament are rigidly contracted so that neither tenotomy nor forcible stretching is of permanent benefit, while in the flexed toes of a clawfoot, tenotomies and metatarsal excisions usually result in satisfactory correction.

The short muscles of the digital phalanges of the foot do not have quite the same unique action as those of the hand. The lumbricales of the hand extend the second and third phalanges as well as flex the first phalanges, while in the toes they flex the first phalanges only. Likewise, the interossei plantaris and dorsales flex the first phalanx only. Contraction of the flexor digitorum longus or brevis will result in acute flexion of the proximal interphalangeal joint and a corresponding dorsiflexion of the metatarsophalangeal joint. Likewise, any binding of the extensor digitorum tendon to the proximal interphalangeal joint such as might occur from injury or bursitis would promote flexion of this joint with dorsiflexion of the metatarsophalangeal joint so that a typical hammer toe deformity would thus be created.

Treatment. The only successful treatment of the typical hammer toe is excision of the proximal interphalangeal joint. Amputation is a serious error because it will permit hallux valgus of the big toe and thereby increase disability. Tenotomy and splinting may temporarily correct the deformity, but relapse is almost certain to occur. In the very young an exception may be allowed to this statement, but even here, excision is found to be preferable to temporizing with inadequate procedures.

The operation consists of excising the corn-like bursa by an oval incision and then excising the articular margins of both phalanges sufficiently to permit the toe to straighten easily. The flexor tendon should be divided as it is of no further use. After suturing so that the excised ends of the bones are closely approximated, the toe is splinted in extension. In ten days the patient can resume the use of a shoe over the splinted toe. It requires about six weeks for union to occur sufficiently to protect against relapse.

SURGICAL TREATMENT OF HALLUX VALGUS BUNION

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THE characteristic hallus valgus deformity of the great toe, commonly termed "bunion," is an unsightly, exasperating disability of the foot, often tolerated for years by the sufferer because of fear of surgical correction. There seems to be a universal idea that an operation will cause the toe to be stiff or useless. It is quite likely that this general apprehension is due to the occasional disastrous results in improperly selected cases and the long period of disability following such procedures as resection of the metatarsal head or osteotomy fractures of the shaft of the metatarsal.

Since more than fifty different procedures have been described it is quite indicative that satisfaction in surgical technique is difficult to obtain. A successful operative procedure is one that fulfils not only the surgical requirements in correcting deformity, but also the patient's expectations in respect to early return of function, relief of pain, and cosmetic improvement.

A technique previously described by the author* to meet these requirements is one in which the correction is made by releasing the deforming forces directly at their point of contraction rather than by indirectly attacking the skeletal form for realignment.

Pathologic Anatomy. When the anatomy and mechanical peculiarities of the big toe are understood the measures for correction can be applied more directly. The relationship of the big toe to the remainder of the foot is similar to the relation of the thumb to the hand. Each is a structural unit individualized anatomically by an advantageous design of skeletal support and equipped with a specialized mobilizing muscle and tendon system. The finer movements in the big toe are undeveloped, although highly perfected function may still be seen occasionally in natives of isolated areas or where congenital loss of the hands has induced substitution of the toes.

A distinctive feature of construction is that none of the muscles of propulsion is inserted in the first metatarsal shaft or head. The tendon action is referred entirely to the phalanges, whereas the metatarsal shaft with its free rounded head and its ligament bound base serves as a fulcrum to the toe action, and as an abutment to the weight-bearing forces transmitted from the keystone tarsals of the arch. Normally in the unshod foot there is an equilibrium between the abductor and adductor forces acting on the proximal phalanx of the big toe. The wearing of shoes, however, gives advantage to the adductors so that when bursal or articular disturbances arise, the resulting contraction produces a valgus of the toes. As the deformity progresses the transverse axis of the metatarsophalangeal joint becomes oblique and the tension of the extensors is added to that of the adductors to spread the head of the metatarsal medialward and the toe outward.

Treatment. The extent to which the deformity and pathologic changes have developed will determine the degree of surgical interference. The bursitis and arthritic changes may be severe or mild. The deformity of the toe may be very moderate, yet the pain and disability may be severe, or the deformity may be severe and the symptoms very mild. In children and young adults much may be done by proper measures of prevention, but when

* MCBRIDE, E. D. Conservative operation for bunions. *J. A. M. A.*, 105: 1164, 1935; *J. Bone & Joint Surg.*, 10: 735, 1928.

pathologic changes have arisen there is little to be expected from appliances or non-surgical measures.

The objectives toward which correction of the deformity must proceed are as follows:

1. Restore the transverse axis of the metatarsophalangeal joint and return the phalanges to their normal weight-bearing line.

2. Approximate the diverging head of the first metatarsal to the second metatarsal.

3. Permanently relieve the overwhelming stress of adductor tension to prevent relapse.

4. Remove the painful factors of bursitis, exostoses and sesamoid displacement.

Essentials of the Operation. The conjoined tendon of the adductor hallucis and the lateral head of the flexor brevis is released from its attachment to the base of the proximal phalanx and transplanted into the lateral side of the first metatarsal head, using sutures that will draw the first and second metatarsals tightly together. Additional relaxation is obtained by removal of the lateral sesamoid which, in most instances, is demonstrated by *x*-ray to be displaced and acting as a levering wedge to force the first metatarsal head medialward. Both sesamoids should be removed if they are painful.

To accomplish this very tedious work the incision is started near the web on the lateral side of the first toe and extended upward and obliquely medialward along the extensor hallucis longus tendon. After the work is completed on the lateral side of the toe the skin and fascia are dissected and retracted from the medial rotundity of the metatarsal head and joint, so as to expose thoroughly the bursa. The bursal fascia is cut transversely and dissected from the bone and a section removed to permit suturing it together later with tension enough to maintain the toe in slight abduction. When the phalanx has been restored to its transverse axis there is usually much less bone prominence than expected. No more bone is excised from the medial side of the head than is necessary to flatten the surface flush with the shaft of the metatarsal. Care must be used to leave no small spicules of bone or tags of periosteum. As few catgut knots as possible should be used and the wound should be dry before closing. A little time and compression after removal of the tourniquet will usually stop the oozing. During the closing process the toe should be kept in a little over-correction and a plaster spica applied over the toe and ball of the foot. The patient can bear weight in the plaster support about the seventh day. The plaster is changed to a spiral bandage and adhesive plaster support when the stitches are removed about the tenth day. The patient may then be permitted to walk in shoes by cutting an opening to allow for the corrected position of the toes.

SUMMARY

The deformity of hallux valgus can be satisfactorily corrected by releasing the adductor tension which is producing it. Such a procedure affords much quicker return to weight-bearing function than when the more radical procedures of bone resection or osteotomy are used.

CUTANEOUS DISEASES OF THE EXTREMITIES AND THEIR RELATION TO SURGERY*

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THERE is perhaps no specialized field of medicine that does not overlap to a limited extent some other field. It is only to be expected that certain diseases coming within the domain of the dermatologist should also be of surgical importance. While the majority of these might be treated similarly by both dermatologist and surgeon, there are some in which coöperation between the dermatologist and surgeon is conducive to the best therapeutic result. There are others in which treatment of the dermatosis may prevent complications which might require surgical intervention. It is not our purpose to consider in detail all the various diseases of the extremities that one might find described both in a text on minor surgery and a text on dermatology, but particularly to describe certain instances in which coöperation between the dermatologist and the surgeon has worked for the best interest of the patient.

A study of Foote and Livingston's "Principles and Practice of Minor Surgery" reveals at least thirty or more diseases of the extremities which one will find discussed also in the more extensive texts on dermatology. These are in the main as follows:

Burns	Felon	Eczema
Frostbite	Lymphangitis	Chronic ulcer of the leg
Wound infections	Syphilis	Perforating ulcer
Anatomic tubercle	Anthrax	Madura foot
Erysipelas	Tularemia	Callus
Erysipeloid	Sporotrichosis	Corn
Superficial boil	Ganglion	Wart
Carbuncle	Epithelioma	Sebaceous cyst
Paronychia	Sarcoma	Scrofuloderma
Cellulitis	Melanoma	Lymphadenitis

To these may be added glomus tumor, nevus, fibroma durum, onychomycosis, and granuloma pyogenicum.

The surgical and dermatological management of several of these conditions, for example, burns, furuncles, carbuncles, felons, sporotrichosis and epithelioma is so entirely similar that any discussion in this paper seems unnecessary. In others the surgeon is interested in one phase of the disease, the dermatologist in another. For example, in frostbite the surgeon is chiefly interested when the question of amputation arises; the dermatologist is more interested in those recurrent chilblains that so often respond promptly to *x*-ray therapy and local dermatologic therapy. In our presentation we are chiefly interested in (1) those diseases in which collaboration between the dermatologist and surgeon is provocative of the best therapeutic result; and (2) those diseases which, treated by the dermatologist, may prevent the development of later complications which might result in the necessity of surgical intervention. It is the latter group that we wish particularly to discuss. However, there are some interesting points in connection with a few of the other diseases that are of common interest to the surgeon and dermatologist that we will briefly mention.

For example, *erysipeloid*, although usually a mild, localized cutaneous infection, may rarely be expressed as an acute septicemia with a fatal outcome, or as a generalized cutaneous infection with arthritic and constitutional symptoms. The surgeon is frequently consulted because of the confusion of erysipeloid with a pyo-

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genic infection and we wish to call attention to the extensive studies of Klauder[1] who points out that the most severe types of the infection are contracted from a fish source, and furthermore that the source of the infection is usually in the occupation of the patient. Although *lymphadenitis* and *lymphangitis* (which may at times be considered surgical) occur early, they disappear before the involved skin returns to normal and without surgical intervention.

Although furunculosis may require surgical attention, one of us (C. S. W.) has recently[2] pointed out that the majority of cases of chronic furunculosis respond to the internal administration of combined brewer's yeast and tin proteinate given over a period of time.

Fig. 1. Draining sinus from old shrapnel wound with streptococcic dermatitis of surrounding skin. (October 19, 1938.)

Fig. 2. Complete disappearance of skin lesion and healing of the old wound after administration of sulfanilamide. (November 5, 1938.)

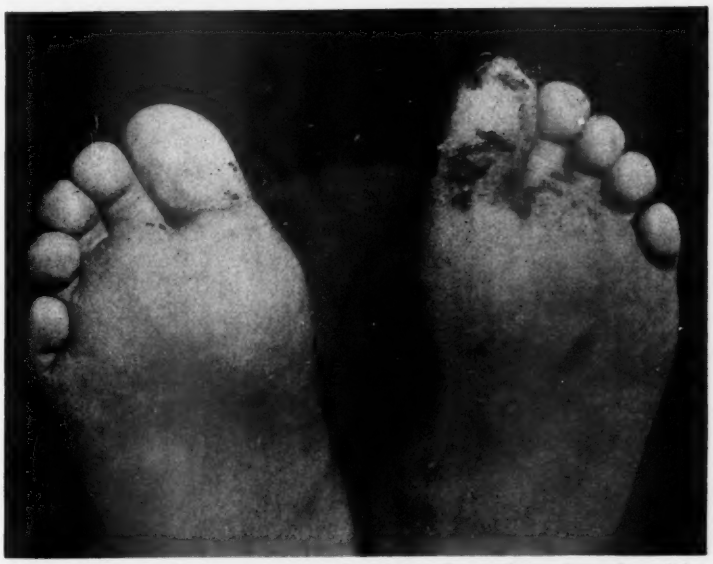

Fig. 3. Dermatophytosis of the feet. Secondary lymphangitis, lymphadenitis, cellulitis, phlebitis or erysipelas may follow.

As an example of a condition in which surgical and dermatological collaboration cured a stubborn wound infection we cite the following case (Figs. 1 and 2.)

Case 1. I. M., a white man aged 39, sustained a shrapnel fracture of his left radius and ulna in 1917. After six operations the wound healed and remained healed for twenty years. About January, 1938 he developed sudden severe pain and swelling in the region of the wound scars. Several days later he was operated on and bone sequestra were removed. A

slightly draining osteosinus persisted. About October 1, 1938 the skin about the sinus orifice became red and painful and spread peripherally. Three weeks later the skin of the upper two-fifths of the extensor surface of the left forearm presented an intensely acute dermatitis, the center of which was the discharging sinus orifice. (Fig. 2.) The patient complained of marked pain, intense itching, and inability to sleep.

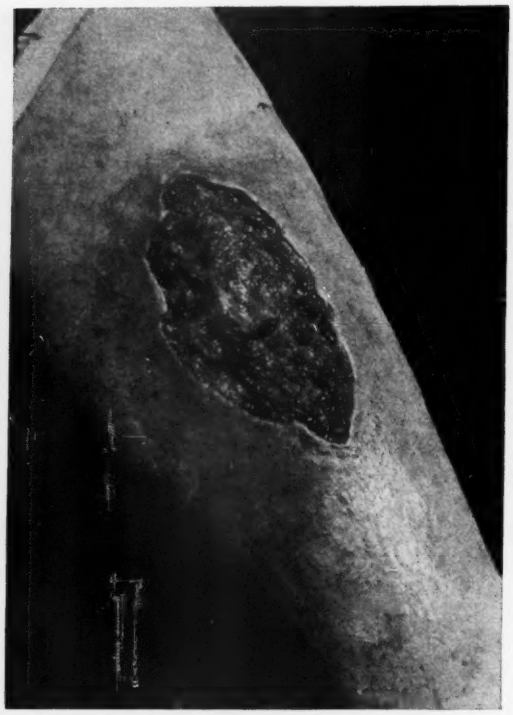

Fig. 4. Chronic ulcer of the leg. Streptococci recovered from the discharge. Infection disappeared following administration of sulfanilamide.

Bacterial culture on blood agar revealed: Aerobic, hemolytic staphylococcus aureus (pure culture); Anaerobic, many hemolytic streptococci (pure culture).

Sulfanilamide, gr. 15, was administered every four hours for a total of 60 gr. the first day, 40 gr. the second and subsequent days. Within two days after starting the sulfanilamide the pain disappeared, itching ceased, the involved area became dry, scaly and pale, and the moisture at the sinus orifice became scanty. Within ten days healing of the skin and wound was complete.

Table 1 presents those conditions which primarily come to the attention of the dermatologist but which may lead to complications that require surgical intervention.

Table 1

Dermatosis	Surgical Complication
Fungus diseases (hands and feet)	Erysipelas
	Cellulitis
	Phlebitis
	Lymphangitis
	Lymphadenitis
Insect bites	Pyodermia
Eczema (varicose)	Chronic ulcer
Plantar wart	Multiple warts
	Ulceration (radiation)
Nevus	Melanotic carcinoma
Syphilis	Periostitis
	Perforating ulcer
	Gummata

Fungus Diseases. Traub and Tolmach,[3] in 1937, reported eight cases in which an erysipelas-like eruption complicated a dermatophytosis and stated that there could be no doubt that fungi had produced the erysipelas-like eruption. McGlasson and Amoss had previously assumed that streptococci were the causative agents in recurrent erysipelas of the legs associated with infections of the feet. Later, in 1937, Sulzberger, Rostenberg and Goetze[4] also reported cases of recurrent erysipelas-like manifestations of the legs associated with fungus infections of the feet.

One of us (C. S. W.) saw in consultation with a surgeon a woman who had had within a period of a few months two successive attacks of phlebitis of one leg, but at the time of the consultation presented an erysipelas-like eruption of the same leg with a temperature of 103°F. Attention was called to interdigital fissuring and scaling of the foot and microscopic examination was positive for fungi. Following antiparasitic treatment of the foot with involution of the dermatophytosis there were no further attacks of phlebitis or erysipelas.

The authors (Fig. 3) have seen cellulitis, lymphangitis and lymphadenitis extend from or complicate a dermatophytosis. Incision of pustules and vesicles and the constant application of wet dressings to the feet invariably suffice to clear up all complications.

Insect Bites. Secondary infection of insect bites may result in ecthymatous

lesions producing superficial or moderately deep ulceration. Surgical intervention is rarely necessary as the infected lesions respond promptly to the application of ammoniated mercury.

Fig. 5. Multiple plantar warts of feet. Patient had been treated with *x*-ray, strong salicylic acid and plasters. (Courtesy of Dr. John B. Flick.)

Fig. 6. Groups of warts removed surgically and areas covered with pedicle flaps. (Courtesy of Dr. John B. Flick.)

Eczema. Eczema of the leg is of interest to the surgeon because it may precede or accompany a chronic ulcer. Ulceration may result from scratching a streptococcic infection or from breaking down of an underlying varicose vein. The following case (Fig. 4) presented at the October, 1938 meeting of the Philadelphia Dermatological Society by Dr. C. S. Wright and Dr. Reuben Friedman, is an example of a *chronic streptococcic ulcer of the leg responding to sulfanilamide*, as suggested by Goodman.[5]

Case II. J. V., a white man aged 82, about eight years previously had excoriated a "pimple" on the anterior aspect of the left leg until it became raw and bleeding. A progressive ulceration developed which, despite all therapy, never healed. On first examination there was on the anterior aspect of the middle of the left leg a large, longitudinal, sharply marginated ulcer of roughly oval outline, measuring about 11 × 5.5 cm. in diameter. Near the upper posterior border there was some well-marked undermining of the edges. Pressure resulted in the exudation of serous, yellow-brownish fluid. The floor of the ulcer was covered by heaped up, irregular masses of smooth, shining, granulation tissue bathed in thin, serous exudate, and also showed two small patches of yellow-green necrotic tissue. Most of the margin of the ulcer was merged with the surrounding skin without any undermining of the edge, except as previously noted. The skin for about 4 or 5 cm. around the ulcerated area was violaceous red in color, shiny, thickened, and here and there painful on pressure.

Blood serologic tests were repeatedly negative. Bacterial culture on blood agar showed: aerobic—overgrown with a contaminated growth of B. subtilis; anaerobic—pure culture of hemolytic streptococcus.

The patient was given sulfanilamide, gr. 15, every four hours with marked improvement within two days. The necrotic patches were smaller and drying up. Granulation tissue

appeared healthier. There was little or no seropurulent exudate present. The undermined edges fused with the base of the ulcer. The surrounding skin became paler and there was no more tenderness about the ulcer. Because of the extensive loss of skin, skin grafting by the surgical department was recommended.

Prompt treatment of an itching eczema of the leg or an infection, no matter how slight, may prevent the development of an ulcer.

Plantar Warts. These are by no means rare and in the majority of cases are of infectious origin. Radium and Roentgen therapy is used with frequent success, but at times warts are radioresistant and excessive irradiation may be harmful. If the wart has not entirely disappeared after six weeks of moderate irradiation, Blair, Brown and Byars[6] advise either knife excision and immediate suture or accurately limited cautery destruction. They also recommend that a cornlike scar, following primary wart destruction, be completely excised and the defect if small be closed by skin suture. For larger defects, a pedicle flap including skin and part thickness of pad can be switched from a nonweight-bearing surface of the sole, either of the front of the ball just behind the toes or of the inner half of the central part, and the resulting defect in this area may be covered by a skin graft.

Case III (Fig. 5) was seen by one of us (C. S. W.) in consultation with a surgeon and a radiologist. Radiation therapy had not influenced the growths which spread rapidly until the patient could scarcely walk. Surgical excision and pedicle flaps were recommended, with the result pictured in Figure 6. A few new warts have since appeared and were removed immediately by electrodesiccation under local anesthesia.

FIG. 7. Blue black nevus. Imperfect removal or trauma may result in melanocarcinoma.

Nevi. The dermatologist is the one whose advice is commonly sought regarding the treatment of nevi of the extremities. These are chiefly of significance because of the danger of melanocarcinoma. Melanocarcinoma may have its origin in any mole containing nevus cells but more commonly from the black or bluish black moles.

Because trauma may result in such moles undergoing malignant change, it is usually best to remove them surgically with wide extirpation. The tissue is examined microscopically to determine that all pigmentation is removed. As pointed out by Andrews,[7] "If the extirpation is not sufficiently wide, not only has pathologic tissue been left in situ, but also more harm than good may have been done by opening channels of metastasis into subepidermal layers or into the lymphatic nodes of adjacent regions."

Syphilis. Although the late lesions of syphilis commonly involve the extremities, the manifestations rarely have any particular surgical significance if the true nature of the disease is recognized. In the following case, surgical amputation of the foot was recommended by a surgeon but was avoided when the lesions disappeared under treatment with neoarsphenamine.

Case III. K. A., a white woman, aged 65, developed a fungating growth of the sole following removal of a callus by a chiropodist. The lesion increased in size until the entire foot was deformed and showed multiple nodular and fungating lesions, accompanied by marked pain. The patient gave a history of having received antisyphilitic therapy, chiefly mercury, many years previously. In spite of a negative Wassermann reaction, bismuth salicylate was injected weekly in 2 Gm. doses for three months. The lesions continued to increase in size and number. Several dermatologists who saw the patient were unable to agree upon a diagnosis and a surgeon recommended amputation. In spite of the patient's age an intravenous injection of neoarsphenamine, 0.1 Gm., was given, following which the pain diminished and the lesions gave evidence of beginning involution. After eight weekly injections the foot was entirely normal.

COMMENT

We have presented but a few examples of conditions in which the dermatologist and surgeon have a common interest. We have attempted to show that numerous diseases of the extremities come within the scope of both the dermatologist and the surgeon. Our chief aim has been to indicate that dermatologic therapy properly applied to numerous cutaneous diseases may prevent surgical complications, and that in others the dermatologist should immediately step out of the picture and the surgeon step in.

REFERENCES

1. Klauder, J. V. Erysipeloid as an occupational disease. *J. A. M. A.*, 111: 1345, 1938.
2. Wright, C. S. The treatment of skin infections with combined tin proteinate and brewers' yeast. *Med. Rec.*, 147: 10 (May) 1938.
3. Traub and Tolmach. Erysipelas-like eruption complicating dermatophytosis. *J. A. M. A.*, 108: 2187, 1937.
4. Sulzberger, Rostenberg and Goetze. Recurrent erysipelas-like manifestations of the legs: their relationship to fungus infections of the feet. *J. A. M. A.*, 108: 2189, 1937.
5. Goodman, M. H. Treatment of ulcers with sulfanilamide. *J. A. M. A.*, 111: 1427, 1938.
6. Blair, Brown and Byars. Plantar warts, flaps and grafts. *J. A. M. A.*, 108: 24, 1937.
7. Andrews, G. Diseases of the Skin. Second Edition, 1938, p. 658.

CHIROPODIAL CLASSIFICATION AND TREATMENT OF EPIDERMAL EXCRESCENCES*

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CALLOSITY

Synonyms. Callus; tylosis; callositas.

Definition. A callosity is a thickening of the epidermis usually found on the plantar surface of the foot and palmar surface of the hand.

Etiology. A callosity is the result of some form of mechanical irritation, such as standing or walking in improper footgear. The growth develops primarily as a protection to the delicate structures beneath the skin. It may also result from certain chronic skin diseases, such as eczema, psoriasis, etc. A depressed metatarsal arch is a frequent cause of callus on the ball of the foot.

Pathology. The growth consists of thickened epidermis with the dermis not involved. There is little or no inflammation present unless it is secondary to an injury or infection. The overgrowth may continue to a great extent and frequently helomata develop within the callous.

Symptoms. The lesions appear as variously sized areas of thickened epidermis of grayish or yellowish color. They are usually thicker at the point of greatest pressure, and gradually shade off into the normal skin.

The patient does not experience as much pain from a callosity as from a heloma. The pain produced by callosities is usually of a burning character.

Treatment. After sterilization of hands, instruments, and field of operation, the thickened epidermis is removed with a wide chisel or scalpel. Care should be taken when paring these thickened surfaces not to cut away too much of the callous tissue, as otherwise the patient will experience pain in walking. A shield of felt or moleskin is placed on the part to ward off pressure. If the callus has been caused by displacement of a bone, this must be taken care of with the proper corrective treatment.

HELOMA

Synonyms. Corn; clavus; tyloma.

Definition. A heloma is a circumscribed overgrowth of epidermis with a central core which presses upon the corium.

* Authors' Note: In common with other recognized branches of medicine, chiropody struggled through years of "Preceptor" training and the slow growth of educational and economic expediency in its institutions, without, however, having once lost sight of a goal to make of its calling an ethical pursuit of a branch of medicine. Not as a "cult" did chiropody develop, but as a definite unit of medically trained students with known obligations toward its parent body as well as cognizance of its specialty of practice. This, today, is evident in its well controlled institutions of learning, numbering six in the United States, among which is the School of Chiropody in Temple University. Over a period of twenty years chiropody has attained a remarkable scholastic growth, four full years of teaching and clinical practice leading to the academically accepted degree of Doctor of Surgical Chiropody (D.S.C.). Forty-five of the forty-eight states have recognized chiropody as a medical pursuit through the establishment of State Boards of Examiners composed of physicians or chiropodists or jointly ruled by both professions.

Research being a requirement for classification of a school by the Council on Education of the National Association of Chiropodists, the contributions of the profession of Chiropody should, in the future, provide for the medical world findings of primary importance. At the present date there are research projects under way in the various schools to include: (1) the etiologic factors in the production of callus; (2) the incidence of trichophyton infection in the chemotherapeutic action of various antiseptics; (3) the bacteriology of verruca—the possibility of filtrable virus infection; (4) fungus infections; (5) rubber compounds as substitutes for felt dressings; (6) the use of non-corrosive light weight materials for foot appliances; (7) the significance of shortened calf muscles in chiropody; (8) treatment of heloma by electricity; (9) practical tests in orthodigita; (10) cause and treatment of hallux valgus; (11) relationship of weight-bearing to foot disability; (12) chemical and medicinal treatment of verruca; (13) the use of rubber in the treatment of ulcers; and (14) the use of mecholyl by iontophoresis in circulatory disturbance of the lower extremities.

Size and Shape. They vary in size from that of a pin head to that of a pebble, and are usually conical in shape with base upward and outward, and apex pressing downward and inward.

Classification. Helomas are classified according to their appearance, texture, or composition:

1. Heloma durum—hard corn.
2. Heloma molle—soft corn.
3. Heloma miliare—seed corn.
4. Heloma vasculare—vascular corn.
5. Heloma neurofibrosum—corn containing nerve endings.

Formation of a Heloma. 1. There is an excitation of the cutaneous nerves caused by pressure and friction.

2. This causes an increased blood supply and the dermis immediately beneath becomes congested.

3. The congestion causes a more or less permanent enlargement of the papillae.

4. With the enlargement of the papillae, there is a greater amount of nutrition supplied to this area.

5. Increased nutrition causes increased cell production.

6. Excessive development of cells causes an abnormal upward crowding of these cells.

7. This causes the upper layer of the epidermis to become thickened.

8. This thickened horny layer acts as a counter-pressure and cornification or hardening of the tender cells takes place more rapidly as each succeeding new layer is added to the under portion of that already formed.

9. This causes the epidermis to become transformed into a dense, homogenous mass of cells constituting a callosity the size of which is determined by the area of the papillae involved.

10. As the factors which have produced this condition are continued, that portion which was formed earliest gradually becomes thicker than the rest and thus more pressure is subjected to it.

11. The denser portion, known as a core or nucleus, extends downward and presses upon the dermis.

12. Increased pressure on the dermis causes an atrophy of the papillae directly under the nucleus.

13. With atrophy of the papillae, the growth is now dependent upon the increased vascularity surrounding it. Therefore, the growth takes place on its lateral portions mainly and increases its diameter.

HELOMA DURUM

Synonym. Hard corn.

Definition. A heloma durum is a hard circumscribed overgrowth of epidermis usually found on the outer side of the fifth toe, the dorsum of the three middle toes, the great toe joint, and the plantar area of the foot.

Etiology. Helomata result from pressure and friction. This may be caused by the following:

1. Ill-fitting shoes and stockings
   - (*a*) Short shoes and stockings will cause:
     - Heloma durum on dorsum of toe
     - Heloma durum on distal end of toe
     - Heloma durum on plantar surface under metatarsal heads
     - Heloma Durum on medial aspect of the first metatarsophalangeal joint
   - (*b*) Narrow shoes will cause:
     - Heloma durum on fifth toe
     - Heloma durum on first metatarsophalangeal joint
     - Deformity of the three middle toes with resultant heloma durum on dorsum or distally
   - (*c*) Too large shoes or stockings will cause:
     - Heloma durum on posterior aspect of heel
     - Heloma durum on dorsum of foot
2. Lack of protection from a thin sole or a worn out sole
3. Seams in the sole or toe of stocking
4. Foreign bodies: nails in shoe; sand, hair, wrinkled inner sole

5. Unsuitable materials for foot covering: patent leather, cordovan, snake skin, Scotch grains, crepe rubber sole

6. Deformity or displacement of the bony structures—

(*a*) Downward displacement of one or more metatarsal heads

(*b*) Exostosis formation, particularly at the head of the first metatarsal, and on the dorsum of the foot

(*c*) Malalignment of the interphalangeal joints

Pathology. Helomata are an overgrowth of closely packed epidermal cells arranged in concentric layers. This hypertrophy of tissue usually assumes a conical shape, the base external and outward, the apex directed downward upon the papillary layer of the dermis. The papillae directly beneath the apex become atrophied. There is a more or less hypertrophy of the papillae at the circumference of the heloma. The sudoriferous glands involved do not atrophy.

Symptoms. The patient complains of pain which may vary in character from an uncomfortable feeling noticed only when the shoe presses on the lesion, to a constant throbbing sensation of which the patient is conscious whether the shoe is off or on. The patient will frequently describe the latter condition as a "toothache of the foot." Climatic changes, such as rain or snow, seem to intensify the pain ordinarily existing in and about a heloma durum. This is due to the fact that the horny material which makes up the corn is hygroscopic and tends to become swollen when the air is moist.

The heloma presents a horny overgrowth of epithelial cells of slightly yellow color. A darker, more compact mass appears in the growth, called a nucleus. The skin surrounding the heloma is usually congested, and heat, redness and swelling may be observed.

Treatment. Palliative treatment, i.e., any method of treating helomata non-operatively, consists in the use of chemical agents which desiccate the growth. The agent usually employed is salicylic acid in the form of 25 per cent ointment, which is placed in the aperture of a shield and allowed to remain on the corn for two to three days. When the dressing is removed, the skin appears white and soft. This soft tissue is peeled off the toe. The procedure is repeated until the entire growth is removed.

The application of salicylic acid preparations which, of course, includes all commercial "corn cures," is rather dangerous as the action of the chemicals is hard to control, and in many cases is the cause of severely inflamed or infected toes. This is due to the fact that salicylic acid will not differentiate between epidermis and dermis, but attacks both these layers of the skin.

A patient who has administered home treatment of "corn cures" will often find his way to a chiropodist's office with a very troublesome toe. A blanched appearance is noted superficially, with acute inflammation underneath, and there is often infection.

Treatment of these "corn cure" cases should be conducted along the following lines: (*a*) sterilization of the hands, instruments and field of operation; (*b*) removal of as much indurated tissue as possible without creating a hemorrhage; and (*c*) if acute inflammation or infection is present, application of a wet dressing. If the toe is only mildly inflamed, a suitable pad containing an ointment such as 10 per cent ichthyol or 10 per cent boric acid may be applied.

Operative Treatment. This is the usual chiropodial procedure for the removal of helomata. After sterilization of instruments, proper cleansing of the hands and field of operation, there are three methods or techniques for the removal of these conditions:

1. Complete Dissection. In this technique the entire growth is removed "en masse," a single piece. The cutting instrument, either chisel or knife, is held in the right hand and the thumb forceps in the left, each being held as one would a pencil.

To support and steady the hands, one may let them rest gently on the fourth and fifth fingers. When operating between the toes, the fingers may rest upon and press aside the toes so as to give ample room for operating. The cutting instrument is held in the same plane (flat to the skin surface) as the heloma, and a flap cut is made at the margin of the formation, with care to avoid hemorrhage. With the thumb forceps, the free edge is grasped and raised sufficiently to see the "line of demarcation." The "line of demarcation" is made by the union of the light and dark shades of tissue, the normal being light and the darker belonging to the heloma.

Just enough traction or lift is used on the forceps to overcome the pressure of the cutting instrument, not enough, however, to produce the sensation of pulling. The "line of demarcation" is carefully followed until the entire lesion is removed. When properly performed, the gentle lifting of the excrescence prevents the sensitive tissue underlying the heloma from being pressed upon by the blade of the instrument.

This technique is not an advisable one for the beginner. While it is quicker, more professional and easier on the cutting edges of the instruments, at the same time it is more painful for the patient, more difficult to perform, hemorrhage is more frequent and severe.

2. Partial Dissection. In this method, which is a combination of the preceding and following techniques, the heloma is reduced in size by cutting off the topmost layers in small sections and dissecting out the deeper section (nucleus) in one piece. Again, one holds the cutting instrument like a pencil. The skin surrounding the heloma is held taut. This is accomplished by the spreading action of the thumb and fingers of the left hand acting around the heloma but a sufficient distance away to prevent interference with the operation. When the hands are in position, short sliding strokes of the knife are used to remove the topmost layers of the heloma. Again care must be exercised to keep these strokes in a flat plane to prevent hemorrhage. When the surrounding callus area is reduced to normal (pink) layer, the nucleus which remains is dissected out in one piece. This is accomplished as in the complete dissection method.

3. Minute Dissection (Chipping; Shaving). With this technique the entire heloma is removed in small pieces or chips. The cutting instrument is held as before. The left hand is used to spread the skin away from the heloma. More tension must be used in this method to prevent the skin from "buckling" in front of the knife, causing a deeper cut than necessary with the resultant hemorrhage.

As in complete dissection, these latter two methods have certain advantages and disadvantages. In partial dissection and the minute dissection, chipping or shaving, the technique is much the easiest acquired by the student; it is the least painful method; there is less danger of hemorrhage, and it may be discontinued at any time during the operation. The disadvantages are that these two methods are slower, they resemble home treatment, ragged or uneven edges are more apt to remain, and the instrument edge is soon destroyed.

After the removal of the heloma, the remaining tissue is usually inflamed so that it is well to use some soothing ointment on the part, such as 10 per cent ichthyol. Pressure is avoided with felt or moleskin. according to the severity of the condition, If faulty footgear has caused the condition, it is necessary to prescribe a shoe which will meet the requirements of the individual patient.

Radical Operative Treatment. This method is recommended only in a small percentage of cases. It is not indicated unless non-radical procedures have failed to give the patient relief. A case which does not respond to conservative treatment is usually one of long standing which is further complicated by the formation of an adventitious bursa. Nature sometimes causes this type of bursa to form between the skin and

the bone as an additional protection against irritation.

After complete sterilization, anesthesia is obtained by infiltration with 2 per cent novocaine. The first incision is made along the medial side of the heloma. The second incision is made along the lateral side of the lesion in an elliptical manner. It is started at the same point as the first incision and finished at the terminus of the first incision. The two incisions are deepened to the bone. The isolated tissue is grasped with mouse-toothed forceps and dissected away with a scalpel. The section removed includes the heloma durum and the underlying bursal sac. If any bony enlargement is found at the first phalangeal joint, it is removed with bone-cutting forceps. The skin margins are drawn together with silk sutures. The foot is dressed with sterile gauze and sutures are removed in five to seven days.

The above procedure is contraindicated in the following cases: (1) an infected heloma which is discharging to the surface through a sinus; (2) general debilitating diseases, such as diabetes, or tuberculosis which would hinder the healing of the incision; (3) circulatory disturbances of the foot and leg.

HELOMA MOLLE

Synonym. Soft corn.

Definition. Heloma molle is a soft, white, macerated overgrowth of epidermis found beteeen the toes.

Etiology. It is usually caused by tight fitting shoes or stockings which crowd the toes together, producing an impingement of the skin between them. The skin is thus irritated and an overgrowth of the epidermis begins. The normal function of perspiring continues, and with the crowding of the toes, evaporation is impossible. This moisture, which is acid in character, accumulates and acts upon the skin, causing it to become white, soft and macerated. Any deformity or displacement of the phalanges which causes pressure between the toes is also a causative factor.

Pathology. The morphologic changes occurring in heloma molle are the same as in heloma durum, except that heloma molle is not so deep seated. Inflammation terminating in suppuration is often encountered due to the action of perspiration which may produce a small fissure, permitting bacteria to enter the tissues.

Symptoms. Heloma molle is usually circular in form and grayish white in color. When the growth first appears it does not present a sharp line of demarcation, although later on it becomes very much outlined in comparison to the surrounding normal skin. The lesion is quite superficial and the nucleus is not very deep. The most common location is in the web between the fourth and fifth toes, and on the lateral sides of the interphalangeal joints. Soft corns usually occur in pairs and are found opposite one another. Their location represents the points of greatest pressure between the toes.

The patient complains of a burning, smarting pain which is aggravated on the wearing of tight shoes or on weight bearing.

Treatment. After sterilization of hands, instruments, and field of operation, the thickened mass of skin is cut away. Due to the thinness of the tissue between the toes, extreme care must be taken not to cause a hemorrhage. When all of the growth has been removed, the resulting cavity is cleaned out with alcohol or 1 per cent liquor cresolis comp. and a pad of felt or lamb's wool is placed between the toes. The patient is advised to correct the footgear so that the toes are not crowded. If the condition has been caused by metatarsal derangement, this latter condition should be treated with proper manipulation, massage and strapping.

HELOMA MILIARE

Synonyms. Seed corn; heloma disseminatum.

Definition. Heloma miliare is a small overgrowth of the epidermis composed of a nucleus with little or no surrounding callous tissue.

Etiology. Heloma miliare may be caused by nails protruding in the shoe, poorly mended stockings, wrinkled inner soles or shoe lining, or some foreign substance like grains of sand. A dry skin is usually a contributing cause.

Pathology. The hypertrophy of the epidermis occurs over a very limited area so that the growth appears to be composed of a nucleus only. The surrounding area is not involved except that it may be inflamed.

Symptoms. These small growths are usually grayish yellow in color and are more common in patients with dry brittle skin. Heloma miliare is usually no larger than a millet seed and is usually located on the plantar surface of the foot. As a rule the patient does not suffer the pain caused by other forms of helomata, and only when the lesions appear in great numbers do they become very annoying.

Treatment. After the usual aseptic precautions, these growths are removed with the point of the scalpel or the corner of a narrow chisel. In cases where the lesions are very numerous and appear in clusters, they can be treated with a 25 per cent salicylic acid plaster. The plaster is cut to the size of the cluster and placed directly over the growth. It is allowed to remain in place about five days when the lesions are more easily removed. A moleskin shield is usually sufficient to pad off pressure.

As the skin is usually dry, the patient is instructed to rub olive oil or cocoa butter into the part once a day. This will supply the oil which is lacking and will help to keep the skin soft and pliable.

HELOMA VASCULARE

Synonyms. Vascular corn; blood corn.

Definition. Heloma vasculare is an overgrowth of epidermis in which elongated blood vessels are found.

Etiology. As in heloma durum, the overgrowth of epidermis is caused by pressure or friction. The presence of blood vessels may be caused by the pinching effect of tight shoes or stockings which force these capillaries to leave the papillae and enter the epidermis. The trimming of a heloma durum too closely is sometimes a contributing cause of heloma vasculare.

Pathology. There is a hypertrophy of epidermal cells, but no increase in connective tissue or in the number of blood vessels as in verruca. The blood vessels present in heloma vasculare leave the papillary layer of the dermis and enter directly into the epidermis. Inflammation is usually present.

Symptoms. Heloma vasculare appears the same as heloma durum except that dark red spots are seen scattered throughout the growth. These spots bleed when cut and are not to be confused with the dried blood clots sometimes found in heloma durum as a result of injury. Heloma vasculare is usually found on the plantar surface of the foot and occasionally on the toes.

Pain is more severe than in other forms of helomata and the patient usually complains of a burning sensation even when the foot is at rest.

Treatment. After sterilization in the usual way, a pad of felt or moleskin is placed over the condition with an aperture in the pad just about the size of the lesion. Salicylic acid ointment, 50 per cent, is placed in the aperture and allowed to remain in place for about four days. Then as much of the white macerated tissue is removed as possible. This procedure is repeated every four days until the growth disappears. The application of acids (nitric or monochloracetic) has been suggested for this condition, but the action of these agents is too severe for the average case.

HELOMA NEUROFIBROSUM

Definition. Heloma neurofibrosum is an overgrowth of the epidermis in which nerve endings and blood vessels are found.

Etiology. These lesions usually occur in persons with thin textured, delicate skins. Burnett and Gross have observed that this condition is often found in persons suffering with hyperthyroidism.

Traumatism produced by narrow shoes plays an important part in many cases,

especially when "overriding" causes an impingement of the lateral edges of the foot between the upper of the sole and the insole. Occasionally the condition is found in certain occupations which require the individual to thrust the foot forcibly against some hard object. This is particularly true in truck and bus drivers who are continually applying the clutch or foot brake. Another example is found in men who run large presses, which require the operator to control the machine with a foot lever.

Pathology. The exact pathology of this condition is not definitely known. It is believed, however, that the impingement of the lateral border of the foot, whether caused by pinching from a narrow shoe, or direct occupational traumatism, results in the papillary processes being squeezed into the already thickened epidermis. These papillary processes, of course, contain nerve endings and blood vessels.

The impingement of the papillae also retards the return circulation of the involved area and probably accounts for the congestion which is usually present.

Symptoms. These conditions are most commonly found on the medial plantar edge of the greater toe and the lateral plantar edge of the foot in the region of the fifth metatarsal head.

The lesion appears externally as a calloused area. Upon removal of the callosity there appears a puckering of the underlying tissues in which the blood vessels are visible. These blood vessels present a somewhat woven appearance with some running longitudinally to the surface while others are running at right angles. This twisted arrangement of the vessels is due to the fact that at the sites where this condition is most commonly encountered (namely, the medial and lateral plantar edges of the foot) there is a transition of the long papillae of the plantar surface to the shorter papillae of the dorsal surface.

While the blood vessels may be readily seen with the naked eye, we must rely on the patient's reaction to instruments to detect the presence of nerve endings. The condition is extremely painful upon either direct or lateral pressure.

Heloma neurofibrosum can be differentiated from verruca in that it is not circumscribed, encapsulated, nor of new growth origin.

Treatment. Treatment of these conditions is not very satisfactory, and temporary relief is the best that can be offered under the usual palliative measures. Complete dissection of the lesion is not recommended as it always results in hemorrhage, and an irritation of the nerve filaments which lasts for several days. Careful removal of only the superficial horny layer and proper shielding, accomplish the best results from a palliative standpoint. Unlike verruca, these cases rarely respond to escharotics, such as salicylic or nitric acid.

Radical surgical removal is not advisable because of the probability of scar formation which in turn may cause the patient further irritation. *X*-ray or radium seems to present the most effective means of treating these cases. Even if a complete destruction is not possible, irradiation seems to inhibit further development and to accomplish permanent sedatation by destruction of the local nerve tissue.

Proper shielding and the prescribing of correct shoes is necessary to all forms of treatment.

REFERENCES

Callosity

Runting, E. G. V. Practice of Chiropody. London.
Colburn, H. Art of Preserving the Feet.
Wagner, F. Handbook of Chiropody. London.
Kahler, P. Advanced Surgical Chiropody.

Heloma Durum

Erff, G. The pathology of a corn. *Pedic Items*, vol. 12, no. 11.
Low, D. Chiropodolgia. *Chiropodist*, vol. 1, no. 2.
White, G. A. Local complaints of the feet. *Pedic Items*, vol. 3, no. 1.
Rice, E. C., Penney, A. O., and Reher, W. Dissection. *N. A. C. J.*, vol. 23, no. 12.
Krausz, C. E., and Rowe, G. G. Chiropody Quiz Comp. 3rd Ed.

Mowbray, D. T. Surgical removal of heloma durum. *Chirop. Rec.*, vol. 18, no. 8.
Erff, G. Development and classification of corns. *Pedic Items*, vol. 1, no. 7.
Lion, H. True causes of heloma durum. *Chirop. Rec.*, vol. 20, no. 5.
Joseph, A. Treatment of the common corn. *Chirop. Rec.*, vol. 8, no. 9.
Kennedy, W. A. Corns. *Pedic Items*, vol. 1, no. 5.
Leach, T. Etiology of corns. *Chiropodist*, vol. 18, no. 131.
Forbes, J. Statistics of helomata. *North. Chirop.*, vol. 7, no. 2.

Heloma Molle

Burnett, E. K. Treatment for soft corns. *N. A. C. J.*, vol. 12, no. 11.
Wagner, F. Handbook of Chiropody.
Dorlacher, L. Diseases of chiropody. *Pedic Items*, vol. 2, no. 6.
Ahrens, A. Diagnosis of heloma molle. *Pedic Items*, vol. 5, no. 3.
Carleton, F. J. Shoe therapy rationale. *N. A. C. J.*, vol. 22, no. 2.

Heloma Miliare

Kinney, L. Treatment for heloma miliare. *Pedic Items*, vol. 5, no. 2.
Joseph, A. Textbook of Chiropody.
Thomason, W. Some notes on heloma miliare. *Chiropodist*, vol. 20, no. 163.

Heloma Vasculare

Stevens, C. Cure of a large vasculare corn. *Pedic Items*, vol. 1, no. 7.
Zahn, A. A. Vascular corns. *Chirop. Rec.*, vol. 6, no. 8.
Green, C. A. Treatment of vascular corn. *Chirop. Rec.*, vol. 6, no. 10.
Gross, R., and Burnett, E. K. Practice of Podiatry.
Krausz, C. E., and Rowe, C. Gordon. Quiz Compend, 3rd Ed.

Heloma Neurofibrosum

Williams, G. Neurovascular corns. *Chirop. Pract.*, vol. 1, no. 3.
London, H. Diagnosis of heloma neurofibrosum. *Clin. J. Chirop.*, vol. 1, no. 3.
Gross, R., and Burnett, E. K. Practice of Podiatry.

BOOK REVIEWS

WILLIAM B. WHERRY, BACTERIOLOGIST. By Martin Fisher. Springfield, Ill., 1938. Charles C. Thomas. Price $4.00.

When Charles C. Thomas makes up his mind to publish a top-notch work from a typographical angle he certainly achieves it. As a book to hold and look at, this is a gem . . . the kind of a book one wants to own and have in his library, to take down from a shelf and handle.

It tells us of the life of William B. Wherry, whose daily business was carrying on a fight against the agents of cholera, leprosy, plague, tularemia, glanders, and other forms of microscopic death. He built new pathways in bacteriology, epidemiology, and public health. Dr. Fisher tells of Wherry's ideas of raising constitutional resistance to infection by the use of vaccines; of dyes in controlling infections, and from first to last unfolds to the reader how he furthered medical knowledge and human health.

Well written, it does justice to a man whose life was interesting. To all interested in medical history and the cultural side of medicine we heartily recommend this handsome volume.

TRAITÉ D'HÉLIO ET D'ACTINOLOGIE. Two volumes. Edited by Ch. Brody, M.D. Paris, 1938. Maloine. Price 440 francs.

The publishers claim that this is the first book on heliotherapy, ultra-violet and infra-red radiation therapy in the world. It is a complete and authoritative study to which all the continental heliotherapy pioneers have contributed. It is scholarly, detailed and entirely up-to-date. Indeed, when the whole work was completed, each author provided several pages of addenda to cover the period of editing and printing.

The two volumes contain 1500 closely printed text pages. Although there is no index, there is a full table of contents and detailed summaries at the heads of chapters.

Recommended heartily to those interested in this form of therapy who are ready readers of French. Every conceivable condition in which direct sunlight or the various forms of light radiation can be used is discussed by a master in the field. The earliest history of heliotherapy and actinology is brought to the present.

THE PATIENT IS THE UNIT OF PRACTICE. By Daniel W. Propst, M.D. Springfield, Ill., 1939. Charles C. Thomas. Price $3.50.

This is just the book to give the young physician about to begin the actual practice of medicine. And many doctors of medicine, long at their calling and, at times, weary from their toil, will find much of profit between its covers.

The author tells us his purpose in writing this book "has been to systematize my own knowledge of the general principles underlying the practice of medicine and to arrange that knowledge in a form that will be concise, entertaining the usable for students. Special emphasis has been placed on the *patient* as the unit of practice. To that end, the nature of disease, the diagnostic hypothesis and the principles of treatment have been considered from the point of view of the patient as a whole in reaction to his environmental field." This, in a few words, tells the story.

The book is divided into three parts: (1) The Nature of Disease; (2) The Diagnostic or Working Hypothesis; (3) Therapeutic Principles. It is 219 pages long, clear and well written, illustrated, contains a bibliography at the end of each part, and has a glossary and an index.

TEXTBOOK OF NEURO-ANATOMY AND THE SENSE ORGANS. By O. Larsell, PH.D. New York, 1939. D. Appleton-Century Company. Price $6.00.

This book, written for the first year medical student, will, the author hopes, also serve others who have an interest in the subject.

It is a sound book, well written and with all the earmarks of having been prepared by one who knows and teaches the subject. It is 343 pages long, handsomely illustrated (232 figures, some in color), has references at the end of each chapter, and an index.

An excellent work for the purposes for which it was written.